THE GEOGRAPHICAL REVIEW

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THE
GEOGRAPHICAL REVIEW

VOL. XXV OCTOBER, 1935 No. 4

HUMAN ACTIVITIES AND THE STUDY OF LIFE IN THE SEA

AN ESSAY ON METHODS OF RESEARCH AND EXPERIMENT

Johan Hjort

FIG. 1—An old Norwegian fishing boat (Hjort and Ruud, Whaling and Fishing in the North Atlantic, Fig. 20).

Every day in contemporary discussions of science and social questions we encounter points of view and opinions that not only reject the principles we have recently cherished but assert that the immediate future will create entirely new foundations for research and society. "Pessimistic optimism" is Ferrero's description of this attitude. In biological literature we meet with statements such as the following: "Whereas the older naturalists who lived in the time of Charles Darwin and a little later were intensively interested in evolution, the latter is not at all a popular subject among animal ecologists today, and even less among people engaged upon research in economic biology." "We wish to get down to business, they say, and to find out what is actually happening: perhaps in fifty years time we shall have enough reliable facts to build into a philosophy of animal life."[1]

But facts can be discovered only by scientific workers who possess and apply a method, and a method has never emerged apart from a philosophy. The existence of biology for a period of several thousand years is in itself adequate proof that there is a philosophy of biology. All we may ask, therefore, is whether our own day has raised problems

[1] C. S. Elton: Animal Ecology and Evolution, Oxford, 1930, p. 7.

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calling for a new method and a new philosophy. The circumstance that eminent men of science are asking this question shows, at any rate, that it is highly necessary to examine old and new knowledge in relation to the method that created it and that we must try now to map out clearly the proper course to be followed by biology in days to come.

In the present sketch, which is strictly limited by considerations of space, I propose to base my argument entirely on examples from the investigations I have carried out myself or organized or in which I have participated. In discussing questions of method the experience gained from work done by oneself is always the best material for estimating the validity of the considerations and ideas by which one has been guided. My work has had two separate aims, the study of the animal life of the ocean and the discovery and development of new or better ways of carrying on the Norwegian fishing industries. While engaged in these two very different tasks I have arrived at the conviction that the search for analogies between them is a profitable one.

In what follows I shall first try to develop my view of the origin of human industries and of species and then sketch briefly the experience I have had of the problems of survival, extinction, and fluctuations in existing industries and in stocks of organisms in the sea. In a concluding section I shall attempt a critical estimate of the problem with which we are dealing, namely the legitimacy of the above-mentioned analogies and their value for the biological method and the philosophy that created it.

The Origin and Life Histories of Industries and of Species

Origin of an Industry

At the beginning of the nineteenth century all the coasts of northern Europe were inhabited by a population of fishermen who, with primitive gear and small, mostly open boats, caught enough fish for local needs in the waters near their home ports. Certain fisheries had succeeded in extending their operations, notably the herring fishery, which operated over the whole extent of the North Sea bank, because herring can be salted and kept on long voyages.

A revolution took place toward the middle of the nineteenth century in consequence of many technical inventions and organizational improvements: the invention of the trawl, the steam engine, the steamer, modern transport by land and sea. This technical development made possible the sale and distribution of fresh fish and an enormous expansion of the fishing grounds from the nearest coastal waters to distant banks. An entirely new industry was evolved—the deep-sea fisheries.

Deep-sea fishing originated in an "emigration" from the age-old coastal fishing to a method of working in many respects new. In other words, a cleavage arose between an old industry and a new one with different fields of operations, which meant different working conditions for the fishermen. The art of sailing was replaced by the technique of mechanically propelled craft, the life in open boats by the life of the seaman, local knowledge of the coast by the art of navigation, small capitalism by company capitalism.

Along the Norwegian seaboard a coastal fishery had developed during the past centuries, based on the salting or drying of herring or cod, as commodities that could stand long-distance transport and prolonged storage. The growth of these fisheries had consisted, ever since the Middle Ages, not in any changes in the method of fishing, but only in an increase in the *number* of fishermen.

The Norwegian fisheries thus presented, at the close of the last century, the spectacle of a stagnating industry with technical methods reminiscent of conditions that had long been out of date in the other countries bordering on the North Sea. See, for example, the picture of the typical old fishing boat, Figure 1. It is not difficult to explain this contrast between the fisheries of the different countries as the result of the special conditions that govern human industries—above all, the difference in markets. It had become, however, all the more necessary for Norway to try the new methods that had been evolved in the other North Sea countries.

Thousands of square miles of coastal banks had never been fished; and to cover this enormous area within a reasonable time fishing steamers were chartered to work under special control in places where the research steamer had found indications of good fishing grounds or had had good reasons to expect them. All the information obtained in accordance with this plan was published with charts of the areas investigated giving the localities of the stations where fishing had taken place and lists of the species caught at each station.[2] These experiments yielded the biologically interesting information that the same species of fish (halibut, ling, cod, tusk) were everywhere present on all the edges and slopes of the continental shelf at a depth of 100–300 fathoms. The experiments resulted in a Norwegian deep-sea fishery that, unlike the trawling on the shallower coastal banks, was carried on by motor vessels and steamers using long lines. The letters D on Figure 2 indicate "the new grounds" where fisheries of this kind have been carried on in the wake of the experimental operations; I have termed the operations "social experiments."

Among all these experiments one in particular has yielded results

[2] Johan Hjort: Norsk havfiske (Norges Fiskerier, 1), Selskabet for de Norske Fiskeriers Fremme, Bergen, 1905; *idem:* Fiskeforsøg og fangstfelter (*ibid.*, 2), 1905; Johan Hjort and J. T. Ruud: Whaling and Fishing in the North Atlantic, *Rapports et Procès-Verbaux des Réunions, Conseil Perman. Internatl. pour l'Expl. de la Mer*, Vol. 56, 1929.

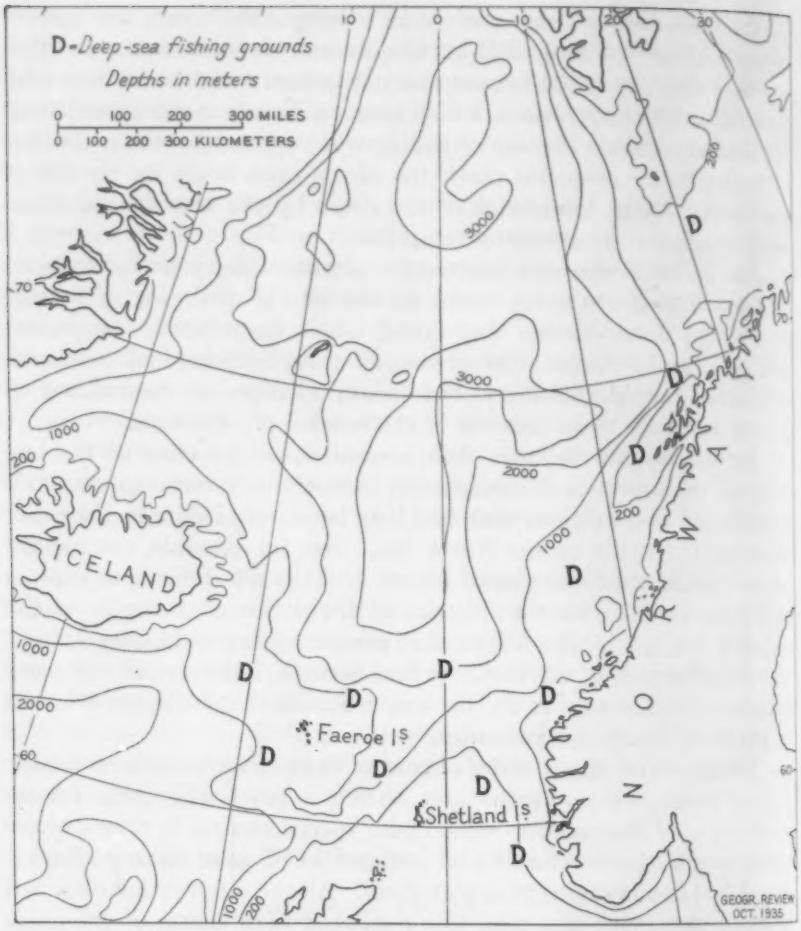

FIG. 2—The Norwegian (or North European) Sea, depths and deep-sea fishing grounds. Scale: 1 : 19,000,000. (Based on Hjort and Ruud, Whaling and Fishing in the North Atlantic, Fig. 21, and, for depths, in part on Pl. XIV accompanying L. A. Boyd: The Fiord Region of East Greenland, *Amer. Geogr. Soc. Special Publ. No. 18*, 1935.)

of especial value for the light that they throw on the general problems we are considering. While engaged in experimental fishing with small fine-mesh trawls I discovered in 1897 that the softest mud at the bottom of the fiords of southeastern Norway was inhabited by an unexpected wealth of the prawn *Pandalus borealis*.[3] After many unsuccessful attempts I managed so to adapt a trawl that it could be dragged along the bottom without the bag's filling with mud. I now found that I could take such large catches that it seemed not improbable that regular fishing by this method might prove remunerative. In the many years since these experiments were made a new

[3] Johan Hjort and Knut Dahl: Fishing Experiments in Norwegian Fiords (Report on Norwegian Fishery and Marine Investigations, Vol. I, No. 1), Christiania, 1900.

fishery has arisen, the growth of which may be seen from Figure 3. In recent years the catches have been up to 4000 tons annually; the special industry that has developed is possessed of a great amount of new information, a new skilled class of "prawn fishers," and an organized trade. Having had the opportunity of following the development from its earliest beginnings, I engaged in renewed experiments in fishing last year, together with Dr. J. T. Ruud and in

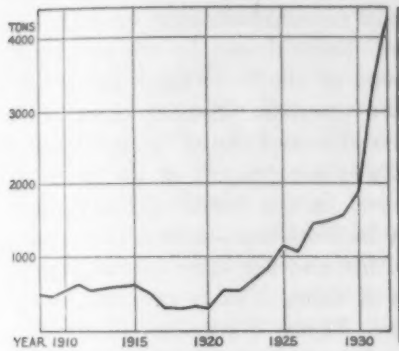

FIG. 3

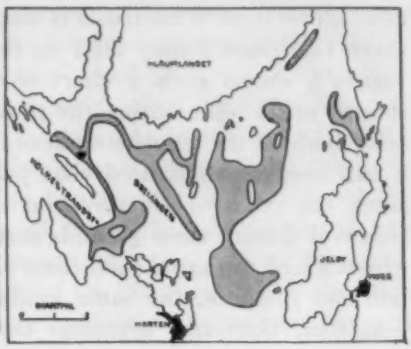

FIG. 4

FIG. 3—Increase in weight of Norwegian and Swedish catch of the prawn *Pandalus borealis.*

FIG. 4—Prawn areas in the outer part of the Oslo Fiord. (Based on a fisherman's drawing.) Scale: 1 : 480,000.

coöperation with the prawn fishers, in order to make a closer study of the new industry.

The bottom of the Norwegian fiords is uneven and irregular like the surrounding landscape. Much as the small holdings of the peasants are dotted about between the mountains or hills, there are in all fiords large or small level areas at the depths (50–150 fathoms) where the prawns live and where a trawl can be used. Here bottom conditions are suitable for the settlement of the kind of detritus on which prawns feed. It requires considerable patience, readiness to profit by trial and error, and exploratory instinct to find these "prawn grounds"; but in the course of many talks with prawn fishers we were surprised at the amount of new information they had collected in previous years. To test this we gave some of the most experienced men charts, upon which they drew all the grounds known to them. In this way we ascertained that several hundred grounds of this kind are now known, all of them discovered by the fishermen themselves. Thus the growth of the prawn fishery is due to long-continued exploratory activities carried on by the men of this industry itself, and these men, moreover, have made the most remarkable observations on the biology of the prawn, its spawning season, its growth, the occurrence of small and large specimens, and much besides. All this knowledge has made possible the development of a new and separate form of

employment, and the natural inference is that all human occupations—farming handicrafts, industrial manufacture, and commerce—came into existence in the same way. The foundation upon which every occupation is built is the discovery of some source of wealth, and of its geographical location, technical utilization, and numerous other factors, including a whole set of biological, technical, and commercial conditions previously unknown.

This foundation is not important only for political economy; the new information it furnishes is also of general biological interest. To make this plain I may refer to the charts drawn by the fishermen. Figure 4 shows such a chart of one of the Norwegian fiords with shaded areas representing the prawn grounds. Similar charts have been made of the whole stretch of coast from Oslo to Trondheim, and it has been demonstrated that prawns are present in the fiords all along the coast of Norway and even in the fiords of Spitsbergen. However distant these grounds may be from one another, they everywhere afford the same conditions of life and the same animal population; for instance, the same kinds of fishes (*Gadus esmarkii*, *Gadus poutassou*, *Gadiculus argenteus thori*, *Phycis blennoides*, *Pleuronectes cynoglossus*, *Chimaera monstrosa*) and various crustaceans (especially *Pandalus borealis* and *Nephrops norvegicus*).

One could hardly find a more convincing example of the correlation between environment and fauna than these hundreds of little fishing grounds so far from one another. If we would explain these communities, we must suppose that the species have been evolved through long periods of adaptation to a very specific environment and that they are found wherever this environment exists.

By studying the charts an experienced man can with a large measure of certainty point out the places where he is likely to find new fishing grounds. But actual investigation may produce results that surprise him. We had one such surprise ourselves while investigating the stocks of prawns in the open sea off the coast. In these waters Norwegian and Swedish fishermen had found a large new ground stretching from the mouth of the Oslo fiord along the slopes of the Skagerrak bank toward the North Sea reef. Here, in a narrower zone at depths corresponding to the prawn grounds in the fiords, abundant quantities of prawns and the same fauna as are in the fiords are to be found. During our cruise in the summer of 1934 Dr. Ruud and I carried on experimental fishing to ascertain how far the ground extends and whether it is continued off the west coast of Norway. We discovered, however, that the prawns abruptly come to an end where the Skagerrak becomes the North Sea proper and the bottom deposits change. Whereas the bottom of the Skagerrak at the depth of the prawn grounds is covered with fine soft mud, the deposits along the North Sea reef are largely mixed with sand. Here

there is no food for crustaceans, which feed on detritus. The nature of the bottom is explained, in turn, by the movements of the current. The Skagerrak, almost unaffected by tides, has still water without any current. Where, however, the coast of Norway swings northward, strong tidal movements begin and the edge of the reef has a hard bottom.

By these investigations, then, we obtained a clearer insight into the specific conditions of life that make it possible for the stock of prawns to exist in its peculiar environment. These conditions, again, determine the sphere of action of the human industry. The industry has likewise specific conditions of work, and its workers have their peculiar professional domain within which they are specialists. A new industry arises through division of labor as an offshoot of an earlier, more comprehensive undertaking or as a result of the discovery of a new sphere of action. It was through the recognition of this fundamental idea of the division of labor that Adam Smith laid the foundation of the science of human society. Similar considerations must guide biology in its study of the life of species in the world of nature, and its first aim will therefore be to investigate the geographical distribution of species.

The Geographical Distribution of Species

"The crust of the earth is a vast museum; but the natural collections have been imperfectly made, and only at long intervals of time. . . . By my theory . . . allied species are descended from a common parent; and during the process of modification, each has become adapted to the conditions of life of its own region, and has supplanted and exterminated its original parent-form and all the transitional varieties between its past and present states."[4] In this passage Darwin admits the influence of environment on the origin of organisms, and logically his admission justifies the hypothesis that there is a specific environment corresponding to each species. Darwin's interest in studying animals and plants in isolated groups of islands or regions marked off by natural boundaries proves that he was convinced of the importance of this point of view. In fact, his investigations yielded extremely interesting evidence that these isolated environments had their own peculiar communities of species. But men of science were unwilling to draw the general conclusion that *all* species must be regarded as confined to their specific environments, because experience showed that many and even related species might inhabit the same region. The problem was evidently highly complicated, the facts were imperfectly known, and the knowledge both of environmental conditions of life and of the life history of species was still in its in-

[4] Charles R. Darwin: The Origin of Species, Murray's edit., 1929, p. 209.

fancy. Nowhere did the problems seem to present more difficulty than in the sea. Yet it has turned out that there is no more instructive environment for the study of these problems.

The continental shelf off the north coast of Norway has a number of small banks on it at depths of about fifty fathoms. These banks are separated from one another by channels two or three hundred fathoms in depth. In the spring of 1902, when I made a cruise in the Norwegian research vessel *Michael Sars* to investigate the pelagic animal life of these waters from an extensive network of stations at short intervals, I found that the floating eggs of the codfish were strictly confined to the banks. Experimental fishing showed that spawning cod were present in millions exactly under the places where the eggs were. This gave us a method by which charts could be made of the spawning shoals of cod by catching their pelagic eggs on the surface of the sea. I succeeded in persuading the International Council for the Study of the Sea to coöperate in making for the whole of the vast area between the Barents Sea and the Bay of Biscay charts that located the different species of Gadidae (cod family) at the time of spawning. The results of this work, in which a number of research steamers participated,[5] showed that each species had a characteristic spawning place of its own different from all the others. As an example of this I may refer to Figure 5, which shows the spawning grounds of three allied species of the genus *Molva* (ling). These three species are morphologically (i.e. in form) very closely related, and yet each has its own "territory." The same is true of the other gadoids, and I therefore endeavored, in the general section of the report, to construct a zoölogical system for gadoids based not on the morphology of the species but on the topographical and hydrographical conditions in their spawning places. In this system I have distinguished between two main groups: the kinds that spawn mostly in the Atlantic and those that spawn in the North Sea. As subgroups in each main group I have distinguished between the kinds that spawn on the coastal banks, on the edges of the banks, and on the slopes of the banks falling down to the great ocean deeps.[6]

Having thus located the positions of the spawning places, we were able to study the conditions of life peculiar to each species. It then appeared that the geographical regions coincided with the limits of certain definite physical conditions. This revealed a correlation between the community of a specific form of life and the conditions in which it exists. But the problem proved to be far more complicated; for the correlation held good only for one stage, viz. the spawning adults and their spawned eggs. The distribution of the

[5] See "Rapport sur les travaux de la Commission A dans la période 1902–1907," *Rapports et Procès-Verbaux, Conseil Perman. Internatl. pour l'Expl. de la Mer*, Vol. 10, 1909.

[6] *Ibid.*, "General Part," p. 68.

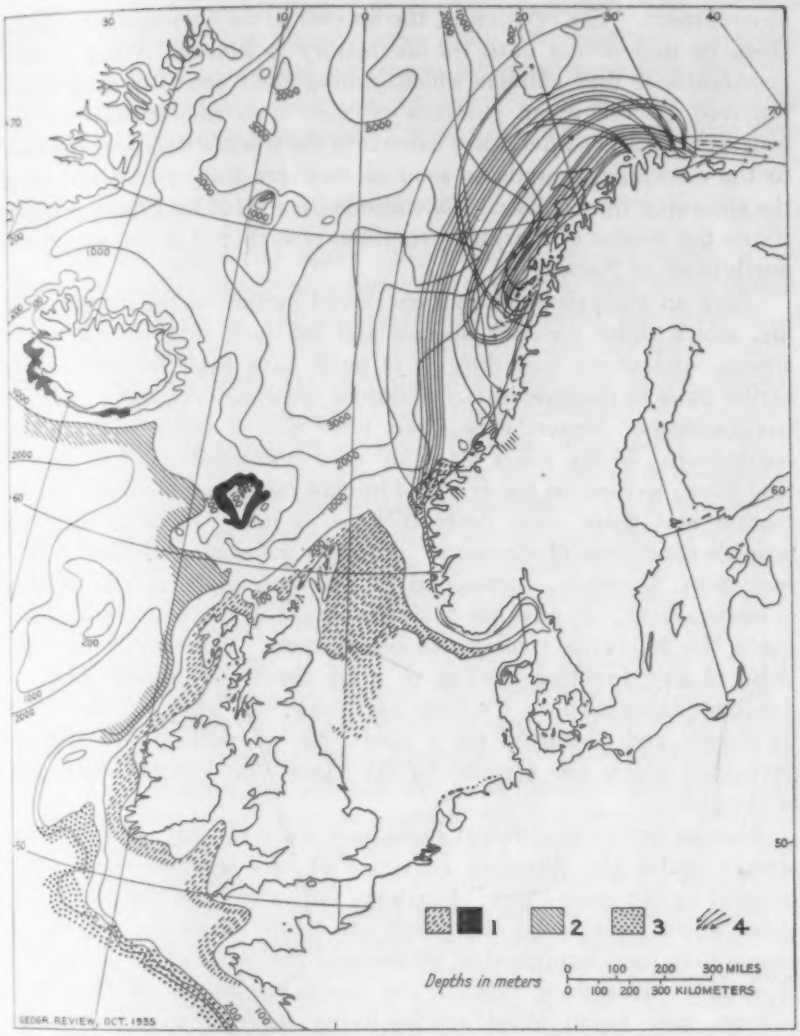

FIG. 5—The Norwegian Sea showing spawning regions of the three species of the ling or genus *Molva* (1, *Molva molva;* 2, *Molva byrkelange;* 3, *Molva elongata;* based on Fig. 18 in "Rapport" cited in footnote 5) and (4) migrations of cod as determined by marking experiments made during the *Michael Sars* Expedition of 1913. Scale: 1 : 25,000,000.

younger stages coincided with other areas, and it was therefore found necessary also to compare the geographical distribution and conditions of life of the corresponding stages of the various species. Here again our study revealed a specific difference between the species—a difference apparently due to the requirements of each stage as regards organisms upon which it can feed and many other things. The young animals must, in fact, be regarded as a biological group entirely distinct from the adults and therefore requiring an entirely different

environment. The relation of the species to its environment cannot, then, be understood until its life history is known. What is most remarkable is that animals which, during their period of growth, are removed by the ocean currents or their own migrations from the geographical areas where they came into the world should migrate back to the spawning grounds as soon as they are fully grown and when the spawning time is near. This also is illustrated by Figure 5, which shows the results of marking experiments with cod in the sea off the north coast of Norway.

Such an analysis gives us a checkered picture of the conditions of life, which differ for each species and for each stage of life in the species, and shows how difficult it must have been for scientists in earlier days to discover the correlations between organisms and their environments. Nevertheless, there were men of vision who saw this connection. Many years after my own investigations I discovered that Kant, writing on the origin of human races, had come to the conclusion that there must necessarily be as many races as there are possible conditions of existence. A *classification of conditions of existence* must, therefore, correspond to the morphological classification of human races. In advance of all the great theories of evolution Kant made the following remarkable observation: "There was no need, then, of any directing wisdom to bring them (the human races) to dwelling-places suitable for their aptitudes; but wherever they came by chance and continued for a long time to multiply, an aptitude developed which was suitable to the climate of that particular part of the globe."[7]

Human beings of different races have since the days of Kant—not always under the directing influence of any wisdom—been intermingled in the same "new" territory, far away from the part of the globe where their racial characters came into existence, and similar events may have happened at all times in the history of many species of fauna. This may explain the many postulates of "modern" authors, who found allied species living together within the same geographical area and who consider this fact a proof of the postulate that the environment has no influence on the origin of races or species. Species come into existence by "accidental" mutations and crossings, they say. I shall return to this question in the concluding section but may offer the following remarks here: The history of the distribution of species is practically unknown. The "habitat" of a species may therefore tell us nothing or very little about the "inheritance of former variations and adaptations," to use Darwin's ingenious phrase.[8] We must accordingly distinguish between two entirely different

[7] Immanuel Kant: Von den verschiedenen Racen der Menschen, in K. Rosenkrans and F. W. Schubert's edition of Kant's works, 12 vols., Leipzig, 1838–1840; reference in Vol. 6, p. 328.

[8] Darwin, *op. cit.*, p. 261.

problems: the *origin* of racial or specific characters and the *survival* of the forms that already have come into existence. A closer investigation that sees the difference between these two problems may discover that the *individual environments* of animals belonging to two allied types may be different within the same geographical area.

Form and Environment

It seemed difficult to apply these principles to the ocean, where the conditions are presumably much the same over vast areas, though the catches taken by earlier expeditions indicated the presence of an untold wealth of different forms of life. After Sir John Murray had generously offered in 1909 to defray the cost of an Atlantic expedition in the *Michael Sars*, I took the opportunity, on the cruise in 1910, of making a systematic study of animal life at different depths of the open sea, where I thought I had the best chance of obtaining a general understanding of the average conditions of life in the ocean.[9] For this purpose the method of fishing was adopted that is shown in Figure 6. Fastened to a steel wire, 5000 meters in length, were as many as 10 different devices for fishing (townets and pelagic trawls), and this complex apparatus was towed along slowly (2 to 3 knots), for twelve hours at a time. I covered so great a distance at a stretch partly because I took it for granted that there was very little life in the sea and partly to neutralize a source of error inherent in the method itself, namely the fact that the fishing gear functioned not only when towed but also while being drawn up. The material obtained turned out to be very comprehensive; during the four months' cruise we caught about 10,000 deep-sea fish, and as a result we gained at least a preliminary knowledge of the vertical distribution of the animal life. Comparison of the catches showed that a number of widely different biological groups of organisms have their habitat between the surface and the great deeps of the ocean. The animal life is found in strata, like the stratified fossils of which geologists tell us. In each layer, for instance, the fishes, even if they belong to different groups, show similar characters; e.g. in the development of their eyes, light organs, and colors. Thus the ocean is divided vertically as well as horizontally into a variety of environments, each having its own specific animal population. The more thoroughly this problem is looked into, the greater is the number of such environments that can be distinguished. Only the outstanding features may be mentioned here.

Vertically three main biological environments may be distinguished: (1) a surface region comprising the upper 150 meters and characterized by transparent or blue animals and young forms of life, especially the members of the large family of Scopelidae; (2) a

[9] See Sir John Murray and Johan Hjort: The Depths of the Ocean, London, 1912.

region extending from 150 to 500 meters and characterized by a community of silvery or grayish fishes belonging to the families of Sternoptychidae and Stomiatidae; (3) a region extending downwards from about 500 meters and characterized by black or dark-colored fishes, among which are the most numerous of all vertebrates, *Cyclothone microdon*, and many invertebrates, notably red prawns.

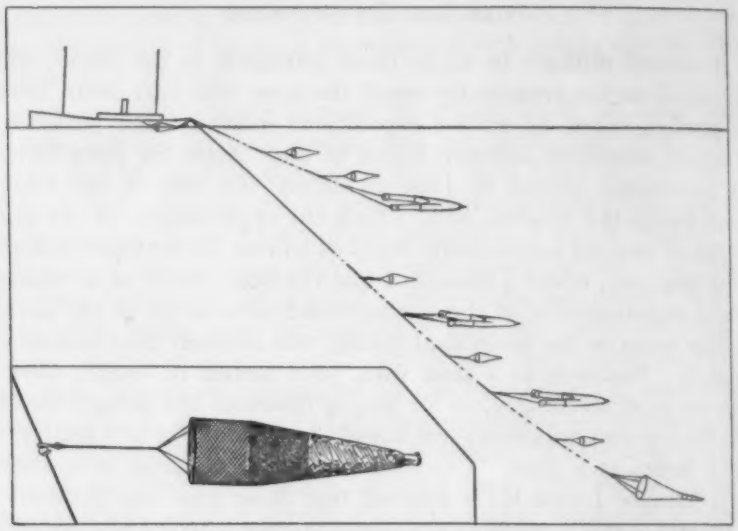

FIG. 6—The *Michael Sars* towing ten nets and pelagic trawls. (Reproduced from Murray and Hjort, The Depths of the Ocean, Fig. 32.)

What makes this material so interesting is the circumstance that, apart from its value in the preparation of charts showing the geographical (horizontal and vertical) areas of distribution of the various species, it raises a number of general and highly important biological problems. No observer, however strictly he may try to adhere to "empirical facts," can help noticing with amazement the remarkable agreement revealed by this material in the forms and conditions of life of the animals. If the observer will compare, for example, the colors of these organisms, the form and development of their eyes, and their wonderful light organs with their surroundings, the principle of adaptation to the specific conditions will seem to force itself upon him wherever he looks. In the surface layers, where the tropical sunshine penetrates the clear, transparent, blue water, are glassy larvae and blue fishes with well developed eyes. The Sargasso Sea has countless small fishes and crustaceans whose coloring is a mixture of the brown of the seaweed and the blue of the water. In the dim region at a depth of 300 to 500 meters the warm parts of the Atlantic have a layer whose conditions of life hydrographic research has found to be very meager. It is inhabited by a Lilliputian fauna, fishes only a

few (3 to 5) centimeters long, whose telescopic eyes turn upwards toward the illuminated region above, from which small dead organisms sink down into their upturned mouths. But the strangest thing here is the coloring. The backs of these fishes are brown or black. These colors correspond to those of the herring, which in boreal waters live at lesser depths but in much less transparent water. The fish are not easily seen from above, because the ocean itself looks dark or black. On the other hand, the light rays are reflected by the mirrorlike sides of the body. From below the eye would have great difficulty in distinguishing the outlines of the fish because of the rays being reflected from the source of light. Finally, in the deepest layer, where the light —or at all events its red rays—has long since been absorbed by the sea water, are black fishes and red crustaceans. The deeper down, the less developed are the eyes of the pelagic fish, many of which are totally blind. All this cannot fail to evoke feelings of wonder in the observer and raise the teleological problem of adaptation. I therefore endeavored, in the report of our cruise, to devote as much time and space as I could to describing and drawing attention to these interesting facts and the problems suggested by them.[10]

Form and Function and the Origin of Species

In the light of the foregoing account of the origin of human industries I shall next examine an instance of the way in which an imaginative science endeavors to use the analogy between human activities and events in the animal world to explain the origin of organisms. I am not frightened by the odium that some have tried to attach to this "teleological" method but shall faithfully follow it, as biologists, however critical, have done ever since the time of Aristotle. The criticism of this method, or rather the consideration of its proper use, may be deferred to the last section of this paper. In the instance to be given here I base my argument chiefly on ideas put forward in Herluf Winge's famous work[11] and in a paper of my own on whales and whaling.[12]

There is no better method of studying the concept of adaptation to environment than by comparing different types of whales, considering each as representing a different way of exploiting the sources of wealth and means of subsistence in the ocean. Each type of animal reflects the potentialities of development afforded by the sea itself. Our knowledge of the whales of the past may even enable us to reconstruct the conditions that existed in the ocean in bygone days.

In the coastal seas, off the shores where the ancestors of the whales

[10] On this subject see Murray and Hjort, *op. cit.*, Chs. 9 and 10.

[11] Herluf Winge: Pattedyr-Slegter III, Copenhagen, 1924.

[12] Johan Hjort: Whales and Whaling, *Hvalrådets Skrifter No.* 7, Norske Videnskaps-Akad., Oslo, 1933, pp. 7–29.

lived, there were shoals of all kinds of fish, equal in size to our cod and salmon. These were the fish that tempted the land animals to begin hunting in the sea and turned them into fast swimmers and clever catchers of fish. Nowadays the coastal seas support a great many different kinds of whales, the most numerous group being the dolphins, which are typical fisheaters.

But the coastal seas contain other forms of wealth—small fish in such quantities that, taken in bulk, they far exceed the larger ones. There are capelins, herring, sardines, and many others. And then there are altogether different types of animals: crustaceans of innumerable varieties—minute species measuring a few millimeters, which are known as red copepods, and larger kinds, about an inch or two long, the Euphausidae, which our Norwegian fishermen call *kril*.

A whale built like a dolphin, with powerful many-toothed jaws, would never survive if it had to live by catching all these little creatures one by one. But common to the life history of all these small species is the peculiarity that they collect at certain times of the year in such dense masses that they may be caught in a net or a bag. Nature made a similar technical invention when she created the baleen of the whalebone whales. Of these there are two groups. First there are the clumsy right whales (genus *Balaena*), like the Greenland whale, which skim the sea. The body of the whale pushes, as it were, its huge mouth through the water, which filters out through the high grid of long whalebones, while the small creatures are retained. Then there are the strong, rapid swimmers, the finners or finback whales (genus *Balaenoptera*), which "play," as the whalers call it. No sooner do these whales catch sight of a patch of food than they are upon it in a flash: they take a huge mouthful, say several barrels full, of minute organisms and then with their powerful tongues squeeze out the water through the natural filter formed by their short whalebones.

No whalebone whale could survive in those immense wastes of the world ocean where uniform tropical temperatures prevail all the year round. The reason is evident as soon as we tow a net in such seas. The forms of animal life that furnish the nutriment of a whalebone whale are very scanty in the clear, transparent blue waters of the warmer oceans. Only in the parts of the sea that are transitional between the warm regions and the polar regions does a profusion of life develop during the summer. Only in those parts of the sea where the fluctuations of the seasons play a decisive role do substances similar in chemical composition to the manure used in agriculture rise from the depths to the surface. These stores of nutriment from the depths cause the enormous growth in spring, when the sun returns after the long winter. Biologically, the chief interest naturally attaches to one characteristic feature of the economy of the ocean. This is the fundamental fact that the same natural conditions with the same rich sup-

plies of nutriment for the development of life recur annually in the transitional layers bordering on the polar seas in the south and north and, moreover, that both areas, separated though they are by the insurmountable barrier of the tropical seas, foster the same or very closely related organisms, from plants of the simplest structure to the highly developed and complex whales.

A third great group of supplies in the ocean has been discovered by the whales. In all the larger oceans—the Atlantic, the Pacific, and the Indian—are large herds of huge whales, which have found out how to live even in the transparent ocean waters of the tropics. They have, in fact, discovered something that was unknown until the great oceanographical expeditions of recent years: that the ocean has a layer, several hundred fathoms below the surface, inhabited by abundant animal life. Here quantities of big prawns and small fish can be caught with a trawl or large net. These sustain an animal population of huge cuttlefish, including the so-called giant squid, whose body may be as much as ten meters and whose arms as much as six meters in length. To capture these organisms Nature has created special kinds of whale, the cachalot, or sperm whale, and its relative, the bottlenose. These whales are able to dive to great depths—several hundred fathoms—and seize the large cuttlefish in their capacious mouths. The great heads of the cachalots are often covered with sores and marks of the suckers of the giant squid, tangible evidence of battles between the two largest forms of animal life existing today. Such fights are everyday occurrences in the depths of the sea.

Survival or Extinction

In the preceding section I have tried to give a tentative explanation of the origin of species as an adaptation of the forms and functions of organisms to the conditions of life in given natural surroundings. Obviously any such account is based on material inadequate for the solution of the problems it discusses. The same holds good, however, for all the historical accounts that endeavor to explain the origin of human society. The historian can achieve his object only by using his imagination to link up the scanty supply of facts. This applies to more than the origin of species or societies; the sciences of biology and sociology are similarly at a disadvantage as regards the problems of survival and extinction. Origin, survival, and extinction are bound up with one another at every stage of biological research. Darwin was the first to see this: "If my theory be true, numberless intermediate varieties, linking closely together all the species of the same group, must assuredly have existed; but the very process of natural selection constantly tends, as has been so often remarked, to exterminate the parent-forms and the intermediate links. Consequently

evidence of their former existence could be found only amongst fossil remains, which are preserved . . . in an extremely imperfect and intermittent record."[13]

Aware, therefore, of the incompleteness of all the material that can be recovered from the past, modern science tries to approach the problems by studying the events of today. These studies may be said to constitute the new science of population, embracing not only human societies but all groups of animals or plants inhabiting a common geographical area. Whereas the study of human societies can build upon valuable statistics, the study of other populations derives its most valuable representative examples from human industries—for organisms in the sea, from whaling, sealing, and fisheries. As a critical control of these, the biologist carries on experimental researches with cultures of rapid-growing organisms.

An examination of this material convinces one that Nature maintains the most varied types of population, each having its own distinctive potentialities of existence, survival, and extinction. We are confronted by a checkered multitude of possibilities of life and destinies, in which countless physical, chemical, and biological factors play their different parts. This complex picture demonstrates with overwhelming force that no general law can be produced from the depths of the student's consciousness nor reached by mathematical speculations founded on arbitrary assumptions and hypotheses. The general view must be based on the examination and study of specific concrete examples. I shall proceed to consider some of these, dealing in this section with experience gained in hunting a group of animals that human enterprise has more than once brought to the verge of extinction—the whales.

When we remember that whales could exploit the rich and varied stores of the ocean only by evolving a number of different forms—the fish-hunting toothed whales, the cuttlefish-hunting cachalots and bottlenose whales, and the two groups of whalebone whales called right and finner whales—we can readily understand that the history of whaling deals not with one but with many forms of whaling.

The historical accounts make it clear that men naturally began by trying what they could do in the coastal waters, hunting the species easiest to catch. The earliest form of whaling was the capture of small porpoises by fishermen. One may imagine the surprise of the Basque fishermen when they made the discovery that it was not so dangerous after all to tackle the huge Biscay whale, or Northcaper, as it was afterwards called. This experience led to the first whaling on a large scale—the hunting of two kinds of right whales, the Northcaper and the Greenland whale. The enormous industry that grew out of this lasted for centuries and employed hundreds of vessels and

[13] Darwin, *op. cit.*, p. 215.

thousands of men from most of the northern European countries; in its heyday it embraced the whole area from Newfoundland in the west to Spitsbergen and a great part of the Norwegian Sea in the northeast. Altogether different, of course, was the cachalot whaling. This was the whaling industry of the tropical or warm seas. It spread with great rapidity all over the high seas and in its palmiest days, around the year 1850, provided employment for 70,000 men in nearly 1000 vessels. Now this whaling is a thing of the past.

As long as sailing vessels and rowing boats represented the technique of their human enemies on the high seas the stock of finner whales enjoyed a perpetual closed season. By a stroke of genius Svend Foyn saw the revolutionary possibilities of the technique of steamships, guns, and explosive shells and understood that these technical improvements meant an entirely new departure in whaling, opening up immense economic vistas.[14] One of his most serious obstacles was the anxiety with which the new industry was regarded in northern Norway, where the population, wrestling for centuries with penurious Nature, had learned to mistrust every development that might possibly imperil their time-honored means of subsistence. This anxiety has proved altogether groundless. The fishermen's notion, reminiscent of medieval superstitions, that the whales served a useful purpose in bringing the fish to their fisheries along the coast has given way to a recognition that the whales have an independent life history of their own and that the variations in the fisheries are due to fluctuations in the size of the actual stocks of fish[15] and in the abundance of the different year classes.

Altogether apart from this, however, the large new whaling industry that had rapidly spread all over the waters off the coast of Finnmark met with a fate similar to that which had previously overtaken the industries based on the capture of right whales and cachalots. The whalers had to move from one ground to another: from Finnmark to Iceland, the Faeroe Islands, Ireland, Newfoundland, the coast of Spain and Portugal—in fact, all over the boreal area of the North Atlantic. Finally they had to move from the North to the South Atlantic, where Nature provides the same whales, the same animal food, and the same natural conditions in the sea. The history of this development affords a study of absorbing interest. The biologist can learn a great deal from it regarding the relation between hunting and the size of the stock, and also regarding man's capacity to adapt his technical methods and organization to circumstances. I shall confine my attention to the general conclusions that seem to follow from the study of these important events.

[14] For photographs see Gunnar Isachsen: Modern Norwegian Whaling in the Antarctic, *Geogr. Rev.*, Vol. 19, 1929, pp. 387–403.—EDIT. NOTE.

[15] Johan Hjort: Fiskeri og hvalfangst i det nordlige Norge, Bergen, 1902.

In the first place, the history of the industry has taught us that unrestricted whaling, with every technical resource and unlimited expansion of the whaling fleet, has invariably resulted in definite and characteristic developments. At first there is a rapid increase until a turning point is reached, after which there is an equally rapid decrease ending in a complete stoppage. An indication that this development is taking place is the transfer of whaling companies from one whaling ground to another. The international whaling statistics afford full material for a close study of the details of this movement.

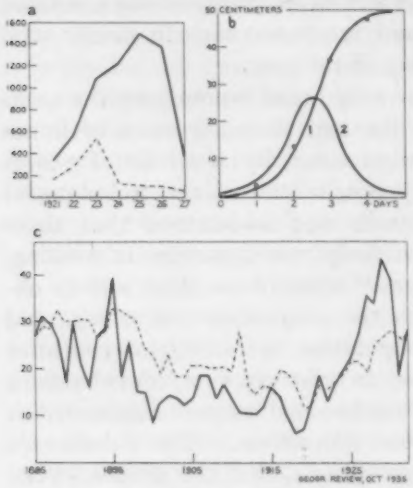

FIG. 7—(a) Fluctuations in the number of fin whales caught off the coast of Spain and Portugal: solid line, total number of fin whales; broken line, fin whales per catcher. (b) The sigmoid curve: 1, growth of a colony of bacteria under limited conditions; 2, rate of growth. (c) The Lofoten fishery, 1885–1932: solid line, millions of cod caught in different years; broken line, thousands of fishermen in the same years.

This naturally raised a problem of the greatest urgency for the Norwegian administration of the whaling industry (the Whale Council), and one of the most important points demanding consideration was the question: is it possible, by limiting the catch, to establish an equilibrium or, as we say, to define the optimum catch? A number of theoretical and practical studies were undertaken, and in 1933 they were collected and published under the title "Essays on Population."[16] In Figure 7a, which illustrates the course of the catch of fin whales off the coast of Spain and Portugal in the period 1921–1927, a fundamental difference can be noticed in the two curves: whereas the curve for the total catch shows a continuous rise until 1925, when a decline set in, the catch per catcher falls off two years earlier. In other words, the continued rise in the total catch was made possible only by the use of increased material, i.e. a larger number of catchers, with the result that the comparatively limited stock perished within a few years.

Here we are up against the great Malthusian problem of overpopulation—a human activity being ruined by its own growth, by the forces that check development and progress, the forces that obey what Malthus termed "the restrictive law of population." Seen in wider perspective, these events in the whaling industry naturally suggest comparisons with the extensive structure of observations and

[16] *Hvalrådets Skrifter No. 7*, Norske Videnskaps-Akad., Oslo, 1933.

thought built up during the last few decades with a view to a better understanding of the growth of populations under different conditions of life. This comparison may be illustrated by Figures 7a and 7b, the former showing the fate of the whaling industry, the latter the growth of a colony of bacteria in a given limited environment. If we compare on the one hand the curves for the growth of the total catch and the growth of the colony of bacteria and on the other the curves for the catch per boat and the rate of growth of the colony of bacteria, we get a point of departure for the hypothesis, or method of investigation. This is to the effect that the future of a population may best be predicted by studying the fate of the average individual enterprise, because this best reflects the possibilities of life afforded by Nature. At the same time the rate of growth may be considered as giving a fair indication of the individual standard of life. Accordingly, the optimum catch, or largest catch consistent with a permanent industry, will be restricted to the number of individuals annually produced by the stock. And our means of ascertaining from Nature what her actual production is will be the statistical study of the average catch of a single boat (catcher). At the stage when the maximum catch has been reached, administrative, business, political, and even diplomatic measures will become necessary to prevent any further expansion of the industry. These ideas had to be faced as live issues at the beginning of the century, when an enormous whaling industry developed in the Antarctic Ocean. Naturally the whaling industry varies in magnitude according to the size of the whaling ground where the stock is found. During the 36 years from 1868 to 1904 the land stations in Finnmark caught 17,746 whales, an average of nearly 500 a year; in the Antarctic, where the area covered is much wider, the catch is far larger, being in the best season more than double the total catch for the whole period of 36 years in Finnmark.

In order to understand this the advance that has been made in the technical equipment of whaling ships must be borne in mind. An enormous expansion of whaling followed upon the technical inventions that led to the building of floating factories. Ships of ever increasing size have been constructed, until now they are equal to great transatlantic liners (more than 20,000 tons); on these ships the whole whale is hauled up to the deck, where a complicated mechanism of windlasses, saws, and cranes quickly cuts it into pieces to be boiled in large boilers of various types.

With a view to studying this great industry the collection of information was begun; and this has resulted in an arrangement by which all the journals of the whaling fleet are forwarded to our laboratory, so that the time and place at which every whale has been caught can now be ascertained. Figure 8 gives an idea of the information

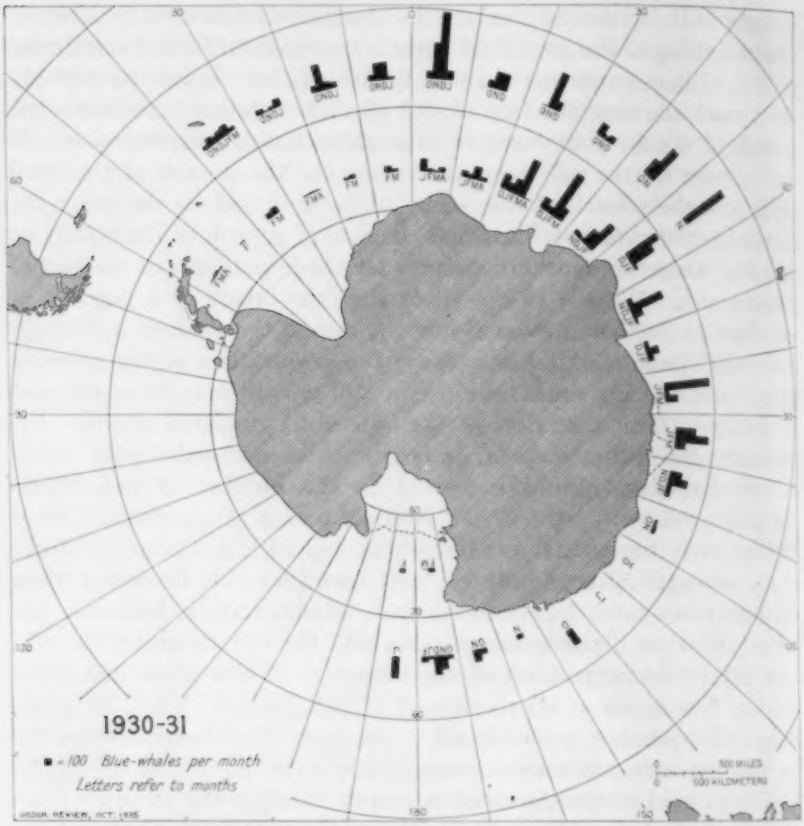

FIG. 8—Number of blue whales caught per month in different "quadrangles" off the Antarctic Continent by Norwegian pelagic whalers in the season 1930–1931. Scale: 1 : 80,000,000. (Based on Johan Hjort, J. Lie, and J. T. Ruud: Norwegian Pelagic Whaling in the Antarctic, I, *Hvalrådets Skrifter No. 3*, 1932, Chart 4.)

thus obtained for the blue whales caught in the season 1930–1931. Similar material for a number of whaling seasons has been dealt with in the reports published by the administration.[17] The results to date suggest that the catch must be considered as having now reached the optimum point or even passed it. I expressed my conviction several years ago[18] regarding the probable effect on the whaling industry if world opinion failed to support the forces working for a limited, rational exploitation of the stock. That statement, which was based on the joint investigations of a number of collaborators, may still be of interest:

> Common to all human enterprise is the peculiarity that a remunerative undertaking tends to expand until it becomes unremunerative for everybody. The greatest problem of organization to be solved by modern society is this: how can a remunera-

[17] See *Hvalrådets Skrifter Nos. 3, 7, 8, 9*, 1932–1934.
[18] Whales and Whaling, pp. 28–29.

tive undertaking be maintained at a high level without sacrificing freedom, personal initiative and individual inventiveness? It is a problem altogether different from what is commonly termed technical rationalization.

In the case of whaling the dilemma is particularly difficult, because this industry is above all others an occupation of the open, free, international seas. A voluntary restriction of the size of the industry, i. e. the size of the whaling fleet, in deference to what is necessary at any time with a view to preserving the stock of whales, would mean the voluntary acceptance of this ideal by all nations. If a country declares itself willing to restrict the expansion of its own industry in conformity with this ideal, as the Norwegian industry did for the present whaling season, such a step ought to strengthen its credit all over the world. But it is also understandable that a country may feel a certain anxiety lest an offer of this kind should fail to receive adequate recognition and support. Not unreasonably it may fear that advantage might be taken of the offer by people who have so far shown no enterprise and made no sacrifices to promote the development of whaling, but who would manoeuvre themselves into a position based on power rather than honest work.

No one, therefore, can foresee the upshot of this great international problem of whaling on the high seas. What is most likely, perhaps, is that the industry will expand till it reaches the limits imposed by the market for its products or by the renewal of the stocks. When that time comes, there will be no question of further expansion; it may even be impossible to maintain the same level, and then the decline will set in.

Two considerations suggest that the stock of whales in the Antarctic will not be exterminated, as was the case with the Greenland whale.

First, the enormous cost of the whaling expeditions to these distant waters will compel the whaling to stop before the whales are so decimated that they are in danger of extinction.

Second, the enormous growth of the whales will favour a comparatively rapid renewal of the stock, provided that numbers are not too severely reduced. In all probability, therefore, the course of events will be as follows:

Our international co-operation will not prove to be so highly developed to-day that it will succeed in establishing the optimal or most favourable equilibrium.

On the contrary we must expect, either that the industry will establish an equilibrium at a lower level, or that there will be fluctuating periods of successful and unsuccessful whaling.

Fluctuations

From the earliest times a characteristic feature in all branches of the fishing industry has been the fluctuation of the yields from year to year. Many years ago there were complaints in the United States about the failure of the mackerel fishery, and in France a "sardine crisis" had arisen, the yield of the sardine fishery, which in 1898 amounted to 50 million kilos, having sunk in 1899 to less than 30 million, and in 1902 to less than 9 million, kilos. The Norwegian fisheries have for hundreds of years experienced alternating periods of rich and poor yields. These periodical fluctuations have as a rule been of some considerable duration, a series of years of profitable fishing succeeding and being succeeded by several years of dearth. In 1714 and 1715 the yield of the fishery in Söndmöre, the district north of the promontory of Stat on the west coast of Norway, was so poor that the fishermen were obliged to sell their boats. In 1718,

on the other hand, the yield was richer in the same degree and remained so until 1733, when a decrease again made itself apparent. In 1736 and 1737 a rich yield was once more noted, which lasted until 1740, when " 'all the bays along the coast were swarming with cod,' "[19] which penetrated far up into the fiords. By 1760 this yield had again fallen to a very low level.

These fluctuations are still more apparent in the literature on this subject in our own time, since excellent statistics are available. Figure 7c shows the varying catches during the period 1885–1932 in millions of cod taken by the Lofoten fishery, an industry that has been established for many centuries. That fluctuations occurred in times when the population was much smaller than now and that they still continue in these days of more intensive fishing carried on in a very limited area by tens of thousands of fishermen is in itself a fact that can hardly be explained except on the assumption that such fluctuations are due not to human activities but to great natural phenomena. This hypothesis would also explain the curve in Figure 7c, which shows the variation in the numbers of fishermen. The work and catch of the fishing population are governed by natural conditions beyond their control.

For Norwegian fishery research the most important task was to try to solve the riddle of these long-known facts of experience, which had been exercising the minds of the fisherfolk for many generations. My first contact with the Norwegian fisheries suggested to my mind that the statistics of the quantities of fish caught might be regarded as a reflection of the fluctuations in the stock of fish. In other words, the stock of fish cannot, like a human population, be regarded as a relatively constant quantity; on the contrary, the numbers of individuals of the various stocks must at different times fluctuate greatly. In a memorandum on the relation between fishing and whaling in northern Norway[20] I upheld this view in opposition to the fishermen's contention that whaling was injuring the fisheries. But no scientific explanation of the problem was possible before the beginning of this century, when it was proved at length that the rings observed on the bones, otoliths, and scales of fishes were annual rings. This meant that not only the age of fishes but their growth and rate of growth at different ages could be ascertained. Figure 9a illustrates this idea and the corresponding method as applied to the study of herring scales.

With the help of such age statistics we could now undertake an examination of the hypothesis that there is a relation between the stock and the quantity of fish caught. What decided me in favor of this hypothesis was the age composition of a number of samples of

[19] Johan Hjort: Fluctuations in the Great Fisheries of Northern Europe, *Rapports et Procès-Verbaux*, Vol. 20, 1914, p. 3.

[20] Hjort, Fiskeri og hvalfangst i det nordlige Norge.

spawning herring taken from fishermen's catches and collected at various points over a distance of several hundred miles along the west coast of Norway (Fig. 9b). It will be seen that these samples agree in that they all contain a numerous year class (the 1904 class) that completely dominates the composite stock. Further investigation showed that the 1904 year class was thirty times as numerous as all the other classes in the stock of herring.[21]

Clearly these methods involved a great many new problems and investigations. Among these I shall mention only the following:

1. Assuming that the life of a year class of herring or cod is 20 years or more and that its decimation by fishing begins as early as the second year, how long (for how many years) can it maintain its numerical superiority? In order to answer this question a control of the stock had to be established. In the past 30 years hundreds of thousands of fishes have been examined to determine their ages. The statistics thus obtained have shown that a large new year class may be the cause of large catches for many years running (Fig. 9d), and this fact has made it possible to issue systematic forecasts of the prospects in both the herring and the cod fisheries.[22]

2. How are we to account for these enormous fluctuations in the composition of the stock? Differences of opinion on this point arose at an early stage. Biology invariably and very rightly tries to trace phenomena back to the influence of physical factors, and accordingly an attempt was made to find a connection between the number of sunspots and the fluctuations in the fisheries. My own view, however, was that the causes must be much more specific. Fluctuations occurred, it is true, in stocks of very different kinds of fish, but the large year classes did not always coincide in stocks of different species of fish, as one would expect them to do if they were directly due to cosmic causes. Observations of the stocks of cod and herring in Norwegian waters showed that a large year class could be detected early in the first year of the fishes' lives and that the abundance of a year class bore no quantitative relation to the abundance of the spawning shoals that produced that year class (Fig. 9d). These facts led me to adopt the hypothesis that the size of a year class was determined at the very beginning of the fishes' lives, when the larvae came out of the eggs and had to find their food in the sea. Their fate was dependent on whether the water happened just at that time to contain enough of the specific organisms on which the larvae feed. Accordingly it seemed probable that the same species of fish would have a large year class if it encountered the same biological conditions of life. When, therefore, the Canadian government invited me to visit Canada in

[21] Hjort, Fluctuations in the Great Fisheries of Northern Europe.

[22] *Ibid.*; Einar Lea: Mortality in the Tribe of Norwegian Herring, *Rapports et Procès-Verbaux*, Vol. 65, 1930, pp. 100–117.

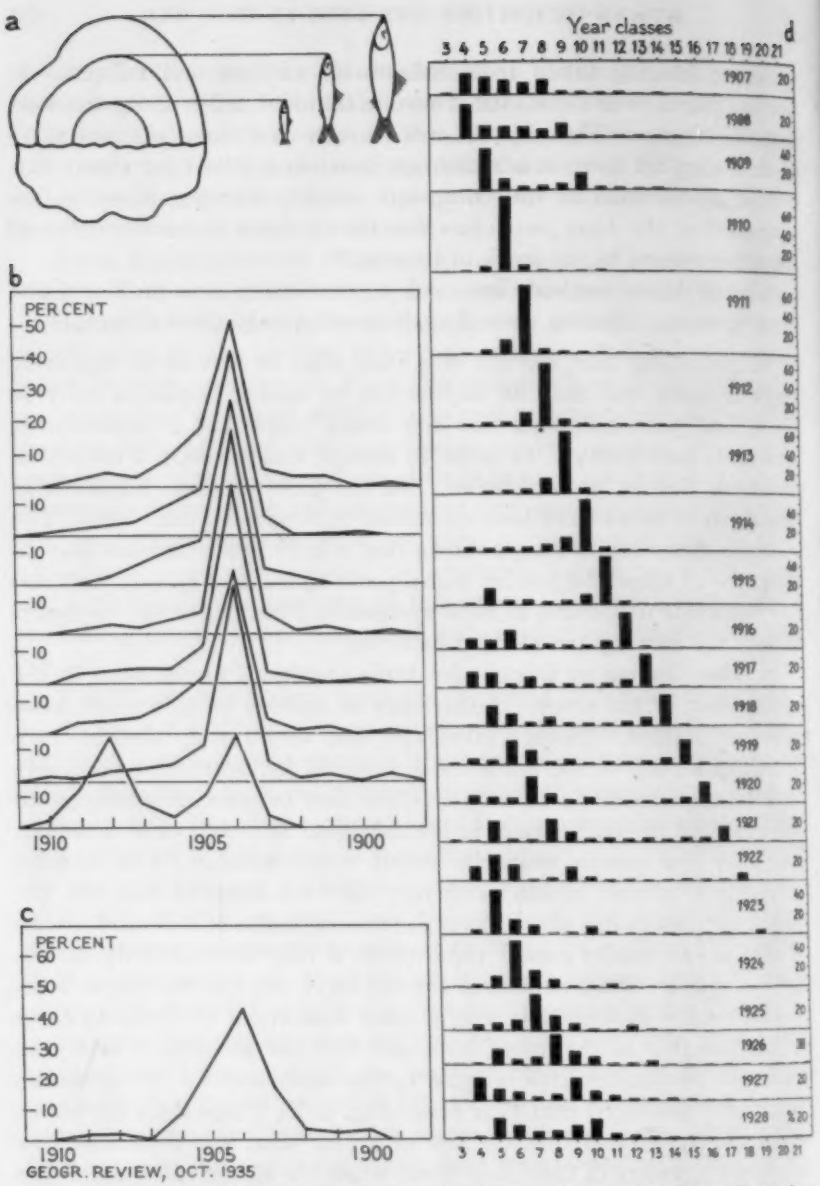

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FIG. 9—(a) The correlation between the growth of the herring and of its scales (Hjort, Fluctuations in the Great Fisheries of Northern Europe, Fig. 10). (b) Age composition of samples of spring herring off the west coast of Norway, February, 1914 (Hjort, *op. cit.*, Fig. 132). (c) Age composition of samples of herring from the Gulf of St. Lawrence (Hjort, Investigations into the Natural History of the Herring). (d) The stock of Norwegian spring herring year by year 1907–1928, illustrating especially the life history of the year class 1904 (Lea, Mortality in the Tribe of Norwegian Herring, Fig. 1).

1914 and to study the fishes there, I welcomed the opportunity of testing my hypothesis that the northernmost tribes of herring along the "pioneer fringe" on the west and east sides of the Atlantic Ocean must be similar in their age composition. And it was highly interesting to find that this was really the case.[23] It will be seen from Figure 9c, which gives the age composition of herring in the Gulf of St. Lawrence, that the 1904 year class played the same role there as it did on the west coast of Norway (compare Figs. 9b and c).

3. The question naturally arises whether this variation in the size of the stock has the effect that the individuals in years when the number is large are of smaller size than those in the years when the number is not so large. Such a question presupposes the time-honored axiom that the means of subsistence that Nature affords are constant, so that the number of individuals must be in inverse ratio to the amount of food available per capita. The celebrated doctrine associated with the name of Malthus and the no less celebrated law formulated by Liebig have consciously or unconsciously given rise to the theory that the numerous year class must necessarily be composed of undersized specimens. Valuable material for the verification of such a theory has been prepared by the Norwegian herring investigations in progress for many years past. These investigations have provided tens of thousands of measurements of the growth zones of individual specimens (Fig. 9a) and of the length of the same specimens. On the basis of such material curves have been constructed illustrating the growth of different species (Fig. 10a), and Dr. Ottestad has definitely proved that the average growth of the different year classes is identical. Figure 10b shows that there is an essential difference between the growth of herring in the waters of southern and northern Norway. This is explained by the different duration of the growth season in these two environments, but in both cases individuals grow equally well in the same environment, irrespective of the numbers in the different year classes.[24] The explanation of this fundamental fact must be that, although the individual fish are doubtless dependent on the amount of food they can get from Nature's larder, Nature had in these particular instances such a large surplus of the requisite food that she could satisfy the needs alike of numerous and of sparse year classes. In the life history of the Norwegian herring the number of individuals in the year classes is determined in the first stages of their lives and not by the amount of food available for the fish at later stages. Nature, in other words, has left such a wide margin of her wealth over and above the requirements of the stock of herring that fluctuations of many hundred per cent can take place within that margin. Com-

[23] Johan Hjort: Investigations into the Natural History of the Herring, Department of the Naval Service, Ottawa, 1915.

[24] Per Ottestad: Statistical Analysis of the Norwegian Herring Population, *Rapports et Procès-Verbaux*, Vol. 88, 1934, No. III.

pared with these immense fluctuations the alternations in the stock due to human intervention, i.e. the fisheries, are insignificant.

Other cases do, however, occur in which the year classes show great differences in the number of fish during the first or the first few years and more equality becomes apparent in the later years. Thus the Scottish fishery investigations[25] have shown that one-year-old individuals of the haddock in the North Sea may differ in the ratio 1:50 in different years without affecting the normal growth of the numerically largest classes but that after some years the difference in abundance of individuals in the numerous and sparse year classes is not nearly so great, because the fishing has equalized the numbers. As regards the plaice in the North Sea, a report on the English investigations[26] is of the opinion that the number of fish of a given year class landed in 100 hours' fishing increases until they reach the age of 3 or 4 years and subsequently falls at a rapid rate.

On the cruise that Dr. J. T. Ruud and I made in the summer of 1934 to study the prawn fishery (see above, p. 533) we found that the stock had greatly diminished on the old grounds where I had taken my first good catches in 1898. An examination of the fishermen's trawl catches showed us that the mesh used in the trawl is so fine that from 10 to 80 per cent of the catch is sometimes thrown overboard because it consists of such small specimens that they are either unsalable or can be sold only at a very low price. We therefore tried trawls with three different sizes of mesh. Figure 10c compares the quantities of both kinds of prawn, i.e. the large, valuable prawns (black columns) and the small, unmarketable ones (white columns), caught with each of these sizes of mesh. Here is an example of an animal population that, like that of the trawl fishery on the North Sea bank, has an extremely large production of young that will always be able to renew the stock on the trawling grounds. Owing, however, to the intensive fishing, the prawns do not have time to reach a size that would support a remunerative fishery. The natural result of this has been that the fishermen have constantly sought new grounds, and as there were plenty of these to be found, the prawn fishery has grown rapidly, as may be seen from Figure 3. Manifestly, however, the time will come when no more grounds will be discovered, and it is therefore very important that a law should be passed making compulsory the use of such meshes in the trawl as will ensure a rational exploitation of the stock.

The problems to be dealt with here are the same as those that have long been engaging the attention of the international investiga-

[25] Alexander Bowman: The Effect on the Stock of the Capture of Undersized Fish: The Haddock Population of the North Sea Plateau, *Rapports et Procès-Verbaux*, Vol. 80, 1932, No. III.

[26] D. E. Thursby-Pelham: Report on the English Plaice Investigations During the Years 1926 to 1930, *Fishery Investigations*, Ministry of Agriculture and Fisheries, Ser. 2, Vol. 12, No. 5, London, 1932. See also Hjort, Fluctuations in the Great Fisheries of Northern Europe, pp. 97–102.

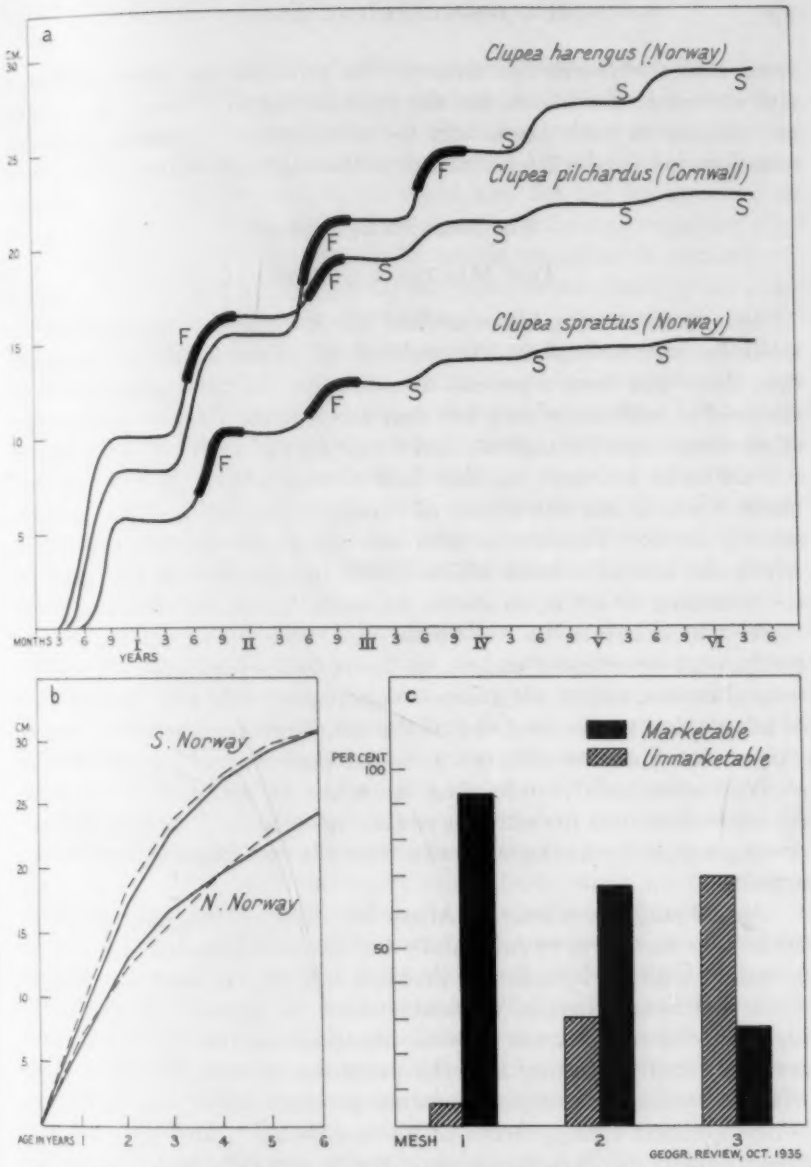

FIG. 10—(a) Growth of herring, sprat, and pilchard. *F*, periods of rich fatty deposits; *S*, spawning periods. (Hjort, Fluctuations in the Great Fisheries of Northern Europe, Fig. 105.) (b) Growth curve of the year classes 1902 and 1904 of the Norwegian herring in southern and northern Norway. Solid lines, 1902; broken lines, 1904. (Ottestad, Statistical Analysis of the Norwegian Herring Population, Fig. 4.) (c) Catch of marketable and unmarketable quantities of prawns in trawls of different sizes of mesh, 1934. (From drawing by J. T. Ruud.)

tions into the North Sea fishery. In principle the same biological and economic conditions for the exploitation of a stock of animals are present in both cases, and the administrative treatment of the questions involved will lead in both to the adoption of similar measures.

The Methods of Biology

The Mental Experiment

It is an interesting historical fact that even in the earliest attempts made by men to explain the multiplicity of organisms by assuming that there had been a process of evolution their thoughts turned to the field of experience they felt they knew best. Man is the measure of all things, said Protagoras, and man's mental activities have always seemed to be his most intimate field of experience. It was this that made Aristotle see the origin of things in the light of the creative artist's work: "The statue does not come into existence of itself. Art is the idea of a work which is still independent of the material, for according as art is, so also is its work." All the creatures which come into existence in Nature do not come into existence by the mechanical or efficient causes, as Empedocles had said. There are several causes, and of the greatest importance is the idea, the principle of adaptation to the final end of the development (the *causa finalis*). "In works of nature adaptation to the purpose and its achievement play an even greater role than in works of art." In such words Aristotle described his entelechy, his "teleological" method of interpreting nature by analogies drawn from his own practical and mental activities.

As we read the works of Aristotle—for instance, his remarkable book "On the Parts of Animals"—we are conscious that his mind is wrestling with an insuperable problem full of deep-seated contradictions and heterogeneous elements which he appears to see but is unable to harmonize: the formless material and the formed piece of art, the blindly working and the purposive cause. Merely to have felt this opposition and the immense problem underlying it was one of the greatest achievements of human thought, and criticism that fails to grasp this is very unjust. But it certainly had a paralyzing effect upon Aristotle's successors, even those of the present day, in that they have either accepted his teaching as a solution of the problem or rejected the problem as alien to scientific thought. It is from this philosophical problem and from the general bewilderment as to the application of the teleological method that "the pessimistic optimism" taken as the starting point of this paper has arisen.

No thinker has done more to solve the philosophic problem associated with the teleological method than Immanuel Kant. In his "Kritik der Urteilskraft" he speaks of living creatures in terms which

closely resemble those of Aristotle. Living creatures are to Kant, as they were to Aristotle, an organized product of Nature, in which everything is an end in itself and is nevertheless (*wechselseitig*) a means. "If, for instance, we look at the structure of a bird, its hollow bones, the way the wings are placed for flight and the tail for steering, we must admit that all this would be quite fortuitous, regarded as a product of Nature (*nexus effectivus*), unless we called in the aid of a special sort of causation implying purpose (*nexus finalis*). In other words, Nature regarded as a mechanism might have made its product in a thousand other ways without producing a whole in accordance with this particular principle."[27] But to Kant the concept of a cause is inevitably bound up with the idea that the cause must precede the effect in time. This order cannot be reversed. A phenomenon cannot precede the thing which caused it. It is therefore impossible to imagine such a thing as a cause in the future, i.e. a *causa finalis*. Such a "cause" exists only in ourselves, in the domain of thought. The "teleological method," which for thousands of years has played such an important role in biology, must, therefore, be recognized as a historical, a retrospective, a regulative and critical estimate of events *that have already taken place and led to a known result*. If we study the development of a bird, it is the previous knowledge of the structure of this animal that creates the idea of a prëexisting goal, of a *causa finalis*. Biology has long ago discovered that no living being ever arises from the formless material. The new individual arises not, as Aristotle argued, out of formless matter but on the contrary from a highly specific structure. In the same way no species arises from anything formless; it arises from other existing forms. Every change is a change from one form or structure to another, and these changes are never "fortuitous." Nature would never be able to create a specific structure in "a thousand other ways." Instead of the *causa finalis* we discover a complex of "conditions of life," the environment which "guides" the changes from one structure to another. Nevertheless the artistic and creative imagination endeavors to arrange the facts of past experience between two different stages in the series of changes that we call history or evolution in the way that a human intelligence might have arranged them with a view to producing the existing phenomena. In the course of this experimental activity experience constantly shows afresh that the available facts are too scanty and incomplete for a constructive grasp of the end in view. This is why the teleological, the historical or *reconstructive*, method constantly leads to fresh demands for further investigations aiming at the discovery of new facts and experience. And this explains to us how the reconstructive method or experiment comes to have the

[27] Immanuel Kant: Kritik der Urtheilskraft (Philosophische Bibliothek, Vol. 39), Leipzig, 1902, p. 232

heuristic value which has made it a method indispensable to all biology. By setting problems and pointing the way to new investigations it gives rise to fresh knowledge, though it often perishes in the attempt when the truth proves to be stranger than fiction. The reconstructive method is therefore to be considered as the mental activity which builds the *framework* for research and experiment in Nature. It is indispensable for all human activities; and it has played a most important role in physics and all practical work as well as in biology throughout the ages. "Ce n'est pas que nous rejetions les hypothèses de la science," says Claude Bernard, "elles n'en sont dans tous les cas que les échafaudages; la science se constitue par les faits; mais elle marche et s'édifie à l'aide des hypothèses."[28]

But in all human activities it often happens that the framework is mistaken for the building. The research and experiments which were intended to erect the building have been discarded as unnecessary, and in the exuberance of imagination the teleological method is applied from the assumption that the human mind can anticipate a *future* development and by deductions from a system constructed by the mind reach the *unknown* result which experience has not yet revealed, because an analogy is assumed to exist between the mind's own activity and events in Nature. The intellectual activity of man is attributed to Nature, and thus the problems of Nature or society may, we are told, be solved by pure reason and "planning activities." It was this confusion of the activity of the subject and the object which made Aristotle believe that the creations of Nature did not come into existence of themselves but had to be created by an analogy with his own mental activities. It was this confusion which led his successors into the blind alley that ended in the dogmatic systems of the Middle Ages. Theories like that of *vitalism* and *psycho-Lamarckism* are still fighting for their existence. These theories may sometimes forget their own dogmatic creed and then give rise to new and valuable experiments, but their danger is that the enthusiasm they arouse often leads to the belief that the mental activity has reached its goal by its own effort without a verifying experiment in Nature.

For the understanding of the methods of biology it is therefore of great importance to remember the warning of Kant that no mental experiment, no analogy, will ever be a reliable guide for our understanding of events to come or for the planning of the future. All analogies, however plausible, will have to be verified by an experiment that we can follow and control from the beginning to the end.

Anyone who has caught a new form of animal life will remember how the thought of other "allied" species arose in his mind and how he experienced the desire to see or verify whether this new creature had a heart, nervous system, intestinal canal, and many other familiar

[28] Claude Bernard: Leçons sur les phénomènes de la vie, Paris, 1885, p. 32.

features of species already known. It is not, therefore, a root principle of this comparative method that man should always be taken as the known point of departure. In many cases biology has discovered important phenomena in animals which it has recognized later in man. The whole science of experimental medicine is now based on this fact. In recent years biology has learned much from sociology and applied its instrument, vital statistics, in studies of all kinds of animal populations. Sociologists have—somewhat arrogantly—brushed aside the biologists' efforts to elucidate the general problems of populations by experimental studies in the propagation of bacteria, yeast cells, or banana flies. Should biology, however, succeed in working out an experimental method which will replace the experiments of social theorists and politicians with human beings by experiments with other organisms that will furnish the first clues to the problems, the lives of untold millions of human beings will be happier. There can hardly be a more important task in our time, therefore, than that of elucidating the principles of the art of scientific and social experiment.

The Problem of Evolution

When Darwin declared that the diversity of organisms was due to their descent, scientists and philosophers asserted that the days of the teleological method were numbered. And yet no book has ever been written, as far as I know, that gives so many and such splendid examples of the teleological experiment as his "Origin of Species."

> Unintentionally 'man exposes organic beings to new and changing conditions of life, and variability ensues; but similar changes of conditions might and do occur under Nature. Let it also be borne in mind how infinitely complex and close-fitting are the mutual relations of all organic beings to each other and to their physical conditions of life; and consequently what infinitely varied diversities of structure might be of use to each being under changing conditions of life. Can it then be thought improbable, seeing that variations useful to man have undoubtedly occurred, that other variations useful in some way to each being in the great and complex battle of life should occur in the course of many successive generations? If such do occur, can we doubt . . . that individuals having any advantage, however slight, over others would have the best chance of surviving and of procreating their kind? On the other hand, we may feel sure that any variation in the least degree injurious would be rigidly destroyed. This preservation of favourable individual differences and variations, and the destruction of those which are injurious, I have called Natural Selection or the Survival of the Fittest.[29]

The very application of words such as "use," "useful," "close-fitting," "adaptation," "favourable," "injurious" denotes the teleological train of thought.

Aristotle would have called "The Origin of Species" a great artist's vision of the creation of species; Kant would have declared it to be a wonderful program of research. Historical research into the life of

[29] Darwin, *op. cit.*, p. 98.

peoples and into the origin of species always has to start from the existing phenomena and must therefore begin its investigations with teleological or reconstructive experiments based on material from the past. But the study and observation of the origin of *new* human activities or the development of new animal populations have the methodical advantage that they can follow the course of events from the outset and thus control the principles created by historical analysis.

It is this consideration that has induced me to give my own experience of industries that it has fallen to my lot to help originate. The experience thus gained has convinced me that a new industry never starts as a conscious pursuit of the final result. As we observe Nature a thought arises of some method of exploiting the wealth that comes in our way. If this is a method suited to other people's mental and social capacities, it will give rise to a new activity, and then the development of the industry proper will follow through the activity of individuals, not with any previous knowledge of the ultimate development and importance of the new industry, but through a series of mutual reactions between the activities of man and events in the social and physical environment. I have tried to crystallize this experience in an analogy between the origin of industry through human activity and the origin of species through activities of the organism. In this form the teleological method may serve to revive an interest in Darwin's program: to investigate the "infinite complexity of the relations of all organic beings to each other and to their physical conditions of life."[30] On pages 535–543 examples have been given of the application of this program and of the problems and investigations to which it leads: the geographical distribution of the species, the relation between its form and environment, and the relation between form and function.

In a previous publication[31] I have tried to formulate my view of the teleological or reconstructive method for the study of the origin of species in these words:

> When we observe the occupation of a particular species we can imagine that it was once unknown; then it was discovered by some organism which was engaged in another occupation, but was well fitted for this one. Accordingly it gradually gave up its own occupation, where perhaps the "competition" was too keen, in order to strike out a new line. The new occupation necessitated to an increasing extent new forms of activity. The new physical and chemical forces and influences . . . changed the form and structure of the organism in conformity with its activities. Thus the old form underwent alterations which gave it a new character. *The occupation, not the new form, represented the aim of the organism and . . . the possibilities of the new occupation existed already. There was no cause in the future—no causa finalis.*

[30] *Ibid.*, p. 159.

[31] Johan Hjort: The Emperor's New Clothes, transl. from the Norwegian by A. G. Jayne, London, 1931, pp. 228–229.

I believe that a dim perception of this view floated through the minds of Cuvier, Goethe, and Lamarck. It seems at any rate to follow from Cuvier's theory of the correlations of form or structure and function or work. Moreover, it is equally applicable to the relation between the work done by animals and the development of their functions, as defined by Goethe and Lamarck. But if we are to grasp the ideas of Cuvier and Lamarck, we must also postulate a relation, strictly determined by law, between the chemical and physical structure and the structure visible to the eye. The invisible physical and chemical structure must be reflected in the form of the organism, as Pasteur found that the molecular structure of organic acid was reflected in the visible crystal. In the same way the changes that take place in an organism must go hand in hand with the formation of the new structural compounds that become incorporated in the old organization. If the forces of Nature that act on structural form create the living organization whose function it is to utilize these forces or the stores they have amassed, function and the genesis of form must obviously go hand in hand. There must always be that relation between function and form that we call the adaptation of a living organism to its environment.

Modern biologists often show their mistrust of the teleological method. Vitalism and psycho-Lamarckism, they say, are sufficient proofs of the fallacies of this deceptive muse. No method, however, should be condemned on the ground that it may give rise to false analogies. A study of the writings of these critics shows the necessity of the method they condemn and the limitations of all scientific research that tries to evade it.

It is the pride of Mendelists that they are able to conduct real experiments by the method created by the ingenious founder of their school. They profess to give an explanation of evolution "that has been deduced from facts, that is in harmony with all other facts, and that completely (*restlos*) solves the problem."[32] "The facts of genetics prove that mutation is the only means by which differences originate in genes that follow Mendel's law." But mutations are discovered *as such* in Nature; they come into existence "by chance," which means that their origin does not interest the Mendelist. Mendelists study not the *origin* of species but the question of *constancy of genes* (under conditions that they themselves consider to be constant). "Species" are *by definition* specific forms, which by genetic experiments have been proved to possess inheritable (genotypical) characters. New species arise as mutations or crossings of mutations. "All varying qualities that are not more or less accidental, like colors, mean nothing but adaptation to a definite habitat in the area of distribution and are still

[32] These quotations translated from Richard Goldschmidt: Geographische Variation und Artbildung, *Die Naturwissenschaften*, Vol. 23, 1935, pp. 169–176; references on p. 175.

included within the idea of the species." In other words, mutations, the material of the Mendelist experiments, come into existence by chance; the facts of genetics are concerned with nothing but crossings of mutations. Other kinds of variations are either accidental or simply adaptations that are of no consequence to the genes. If this school succeeds in avoiding the dangers of teleological thought, it certainly pays dearly for this advantage by entertaining a narrow outlook on life; and nevertheless it does not escape the problems of *adaptation* or the correlations between the form and the environment of the organism. Everything becomes accidental, left to chance or ignorance, if organisms or societies are considered apart from the conditions of life of their environment. There will then be no causes, no ideas for experiments, and very little interest in biology as a scientific work.

Modern literature gives ample proof of the need of a correlation of biological methods. No method is superior or inferior per se. We must avail ourselves of the method that suits the problems and that science commands at the moment. By the application of concepts like the "genes" Mendelism itself gives ample proof that it represents but a preliminary stage on the way to a biochemistry that will replace the genes by chemical structures and the phenotypical and genotypical processes by reversible and irreversible combinations depending on closely defined external conditions.

Physical Science

I have previously[33] tried to show that the teleological method is not a specially biological method but a general principle for all scientific research. It serves the purpose of building a framework or drawing up a program for the study of form and function in Nature. All science must use, and actually does use, this method whether in a legitimate manner or in those fatal aberrations that occur whenever scientific research ceases to make a clear-cut distinction between its own activity and the things it observes in Nature. In speculative physics mathematical constructions play the same role as the mental experiment in biology. In physics the mental experiments of Einstein led to a rejection of the concept of synchrony and those of Bohr to a rejection of causality. Recently Einstein has even stated: "A un certain point de vue, je tiens ainsi pour vrai que la pensée pure est capable de saisir la réalité comme les anciens y ont songé."[34] This is an open confession of adherence to the dogmatic teleology of the Middle Ages.

In mathematical models there is a logical connection between the

[33] The Emperor's New Clothes.

[34] Albert Einstein: Comment je vois le monde, Paris, 1935, p. 169.

elements, but no causal connection: a causal connection can be found only in Nature, where we observe definite occurrences and the conditions governing them. Similarly biology will never be able to apply the principle of causality if it neglects the study of the external and internal environments of organisms. Where this study is neglected we everywhere find that scientific thought returns to "chance," which is nothing but an expression for our own attitude toward the problems. All the recent declarations that science can do without the concept or principle of causality are so much proof that those who argue in this way are studying not Nature or forms of existence but mental models. Even in the study of forms of existence there are some cases in which we can only describe, but in other cases the proof of causality plays a dominant role. We find, then, that in the past history of science apparent differences between methods have repeatedly turned out to be due simply to partial applications of a more comprehensive ideal system, which provides a common method for the whole field of science. Actual experience must determine whether the whole method can be applied in particular cases. But the comprehensive method is universal in the sense that it compels us to notice which parts of it have been used in each investigation.

Sociology

The battle rages around "the social experiment." Here again we meet with the problem of the mental experiment in another form. From retrospective studies of the history of society ideals have arisen that demand the construction of a new and better social organization. These ideals may be valuable because they raise new and important problems. But the experiments that social reformers demand are very often on a much lower level than the historical analysis on which they are based. They apply the method of mental experiment or of deductive conclusions from systems instead of synthetic enterprise. Instead of selecting one special part or element of human activities for experimental research, social reformers demand the right to experiment with society as a whole. In so doing they ignore the truth that no experiment that aims at changing an infinite number of factors at the same time will ever succeed. Thus the ideals become social "isms," which always end in a resort to force in place of experimental success or social service. The remedies once more prove to be "worse than the disease."

A real social experiment always starts from a new *technical* idea—the discovery of a new sphere of work or a new method of work. To begin with, this new departure should always be tested experimentally, the aim being not only to apply the technical ideas on an industrial scale but also to see whether the new technique is applicable in the

existing conditions of life and social structure, i.e. whether the people who are to use this technique are willing and able to adopt the new way of doing things. This is the type of social experiment that eventually gives rise to a new industry.

But experience shows that new occupations are fated to reach a limit beyond which they are incapable of advancing. Perhaps the productive idea, the method employed, is incapable of carrying the development any further. Or Nature's wealth—the size of the stock of fish or prawns or whales—may be limited, thus making further expansion impossible. When this happens we are up against the problem of *adaptation* of the growth of society to the wealth of Nature, the problem Malthus raised and the state of things that biology illustrates by the sigmoid curve (see Fig. 7b). We are confronted by a problem very much like the *static* problem in mechanics—the problem of equilibrium, fluctuations, or extinction, dealt with in previous sections.

In the course of this paper I have given examples, drawn from the fishing and whaling industries, of a line of research that endeavors to build up a system of knowledge for the control and regulation of human industries, on the assumption that it is the duty of the community to give to *individuals* the information necessary or important for their adaptation to the possibilities of the actual situation. This ideal has recently been described[35] as one that aims at "making everyone a 'boss of something,' " whether it be small or great. This ideal seems to be the best of all safeguards to prevent society from adopting plans for unscientific and highly dangerous social experiments.

[35] *Nature*, Vol. 135, 1935, p. 82.

CRUISING BY AIRPLANE

NARRATIVE OF A JOURNEY AROUND THE WORLD

Richard Upjohn Light
Yale University School of Medicine

FIG. 1—*Asulinak* moored for the night on the Tigris River at Baghdad.

A third of a century has now elapsed since sustained flight was first realized. The event was not unexpected; as far back as records go, man had looked forward to the time when he could fly and had envisaged uses to which his aerial vehicle would be put. The extent to which such prophecy was indulged in is truly astonishing; a single sales catalogue lists no less than 54 items published before the balloon flights of 1783 and has 300 pages of listings subsequent to that time. It is of interest to measure these early prophecies against modern developments. The question of interplanetary flights, revived from time to time, may be dismissed without comment. High-altitude flying—so-called navigation of the stratosphere—is being realized to a degree. Mail may be despatched to points in every continent by air. Freight cargoes are winging their way over impassable terrain to remote mines and outpost settlements. Exploring parties now find in the plane a well-nigh indispensable aid. Travelers by common carrier who prefer the speed or the education of aerial transportation find timetables arranged fairly to their convenience. In only one field has the prophesied development of the airplane remained largely unfulfilled: its application to the realm of private travel.

To be of use to individual travelers the airplane must have certain characteristics, some of which have been achieved only recently. Easy maintenance, freedom from breakdown, a relative degree of speed, passenger comfort—these are cardinal virtues. The most important single factor, however, is the extent of cruising range. It is of fundamental significance that designs have reached a point where many of the 1935 airplanes are licensed with a standard cruising range of 1000 miles or more.

This range of flight is sufficient to overcome most of the natural barriers to travel, as one may see by measurement on the map. With

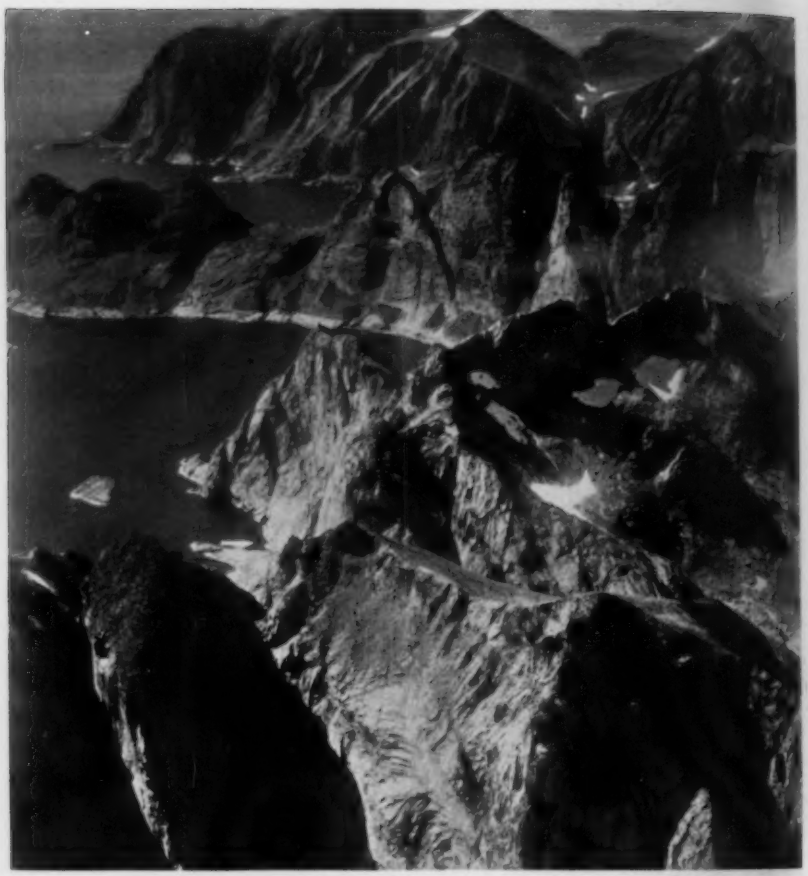

FIG. 2—Cape Farewell, Greenland, looking towards the southwest. (Aug. 29, 1934; 12:45; 4400 ft.; date, local time, and altitude of airplane above sea level are thus given.)

a pair of dividers set to the interval of a safe flight—in the case of a thousand-mile maximum range, 600 miles may be considered a reasonable distance—it can be shown that no continental region is prohibited and that by means of the island routes across the North Atlantic and North Pacific oceans crossings may be made from North America to Europe and Asia. Viewed broadly, an individual traveler may now journey by his own efforts throughout the great belt of the world that lies between the polar circles (barring only the remote islands in mid-ocean) and may penetrate northward beyond the 70th parallel on four coasts. The airplane is ready to answer the dreams of the most hopeful prophets!

To take full advantage of his opportunities the aviator must add other branches of knowledge to his abilities as pilot: piloting itself is the same the world over, for the airplane recognizes no geography save that of altitude and temperature. In venturing away from a

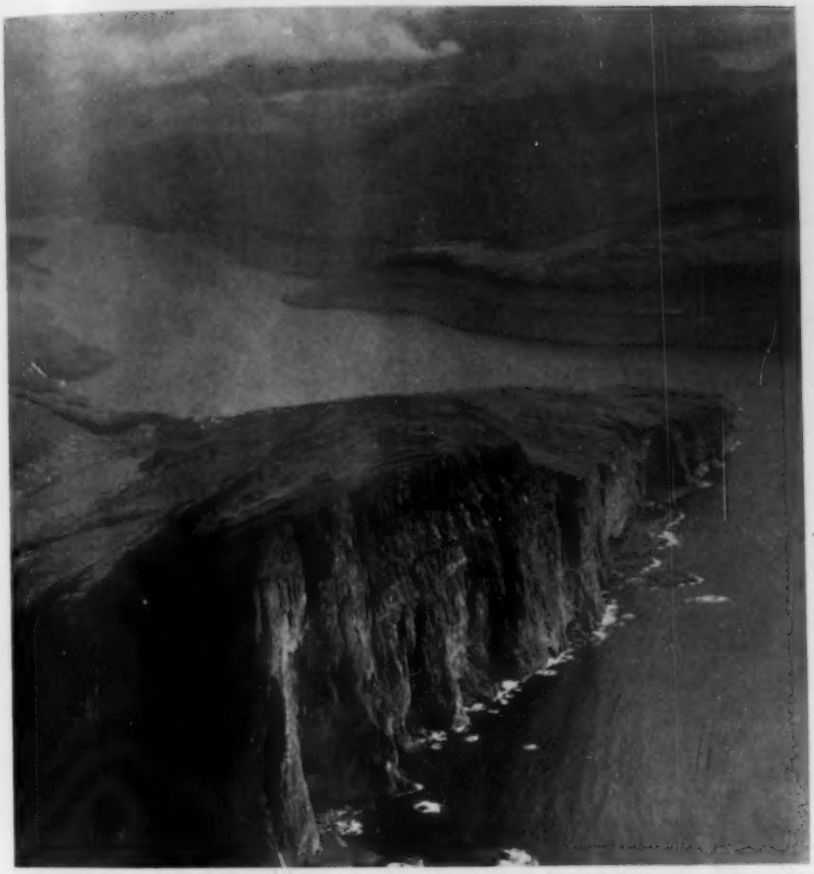

FIG. 3—Looking south into Sundene Fiord, Faeroe Islands. The vertical cliff in the foreground is the northwest face of Kodlur, Österö. (Sept. 5, 1934; 15:30; 2500 ft.)

familiar locality, however, the flier must be prepared in equal measure with the mariner to handle the arts of navigation and communication and in addition should know something of the complexities of international law.

Navigation is his first problem. It is made difficult by the vagaries of the medium through which the journey is made and by the rapid progress from point to point. The subject cannot be dealt with here; it is sufficient to point out that by using drift meter and compass a dead-reckoning course may be flown over land or water with a directional error of less than 2½ degrees, provided the earth is not obscured by clouds, rain, or darkness. When the pilot is driven into or above the clouds, the problems of direction and position may well tax the ingenuity. It is not enough that one understand the solution of routine equations in navigational geometry; it is far more important to recognize without hesitation which of the many aids to navigation

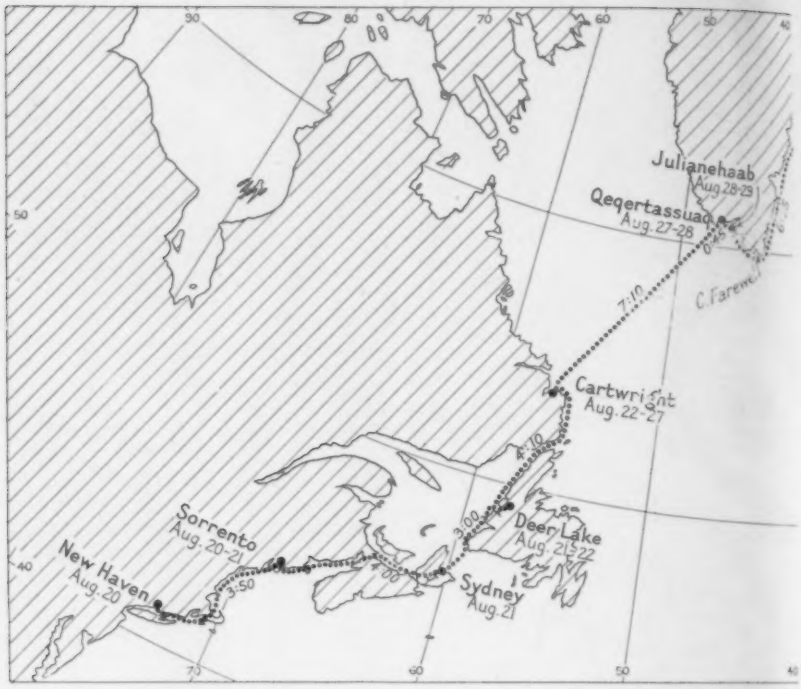

FIG. 4—Stages of the flight across the North Atlantic. Scale of map 1 : 30,000,000.

will contribute information pertinent to the situation in question. To put it bluntly, one must know when to put away the sextant and start hunting for the coast!

Communication forms an indispensable crutch upon which the pilot leans when a decision is to be made. It warns him of trouble long before he reaches it; it gives him news of the day, contact with his family; it is part of his navigational equipment; it is the means whereby assistance is summoned in the hour of emergency. Moreover, consistent communication is a responsibility of the flier toward civilization; no longer is there excuse for the desperate rescue parties that seek blindly for wrecked fliers, who through inexperience or neglect in preparation have been able to give no word of their progress. Radiotelephone equipment is satisfactory in the United States, where uniform language exists and the coöperation of a great network of ground stations is available. In other countries communication is provided best by radiotelegraph, by using the lower marine frequencies for short distances and three or four bands of high frequencies for varying conditions of greater distance and time of day. Modern aircraft radiotelegraph gives reliable two-way contacts over distances of 2500 miles or more.

The narrative that follows is a brief account of experiences met

The flying time is shown in hours and minutes along the route.

with in the course of a seaplane cruise of five months (August, 1934, to January, 1935), during which a distance of 29,000 miles was covered by air. The plane was a Bellanca Skyrocket, a six-place-cabin monoplane powered by a 420-horsepower Wasp radial engine and fitted with Edo pontoons. Built in 1931, the plane had originally been equipped for only a 600-mile range of flight, but for this trip extra fuel tanks were placed in the pontoons, so that the range was increased to 1000 or 1200 miles. A controllable pitch propeller gave aid in the take-offs.[1]

My companion was Robert Wilson, a graduate of Yale University in electrical engineering and an expert in radio communication. Although he had not flown previously, he quickly adapted his skill to the problems encountered in flying. In addition, he learned to moor the plane, take aerial photographs, plot courses, shoot the sun, and repair broken radios while in the air! His sympathies and constitution contributed much to the success of the journey. Most of the photographs that illustrate this article, a few only of the total number, were taken by him while messages were pounding in through earphones that never left his head.

[1] A copy of the author's journal, giving full details of journey and equipment, is on file at the American Geographical Society.

Start of the North Atlantic Flight

The last necessary foreign flying permission arrived at noon on August 20, and by 3 o'clock we had left New Haven and were flying eastward along the Connecticut and Massachusetts coasts. The night was spent with friends in Maine, and next day we continued into the Bay of Fundy, over Cape Breton, and across the Cabot Strait. After our arrival in southwestern Newfoundland near Table Mountain the flight was interrupted now and again to secure photographs of regions then under study by Professors Schuchert and Dunbar of Yale University.

Fig. 5—Looking northeast along the New Brunswick coast at Cape Enrage. (Aug. 21, 1934; 09:24; c. 1200 ft.)

On reaching Corner Brook, we found the harbor full of logs and washed by a heavy swell from the west wind, so we turned inland to Deer Lake and camped on shore for the night. A four-hour journey next day brought us to Cartwright, Labrador, where motor and plane were carefully checked over in preparation for the flight to Greenland. A spell of bad weather held us a few days, but it gave opportunity to watch the valuable work of the Grenfell medical group. During this period, too, Wilson achieved success that we had thought impossible with a small aircraft radio transmitter: he continued three times daily to maintain scheduled contacts with an amateur friend in Hartford, Connecticut.

Greenland lies six hundred miles northeast of Labrador, and the over-water flight promised to hold much of interest, particularly as a navigational problem. I was concerned chiefly with the question of identifying the place where landfall might be made and had planned to reach the Greenland coast by noon, when a sun line of position would intersect the line of the coast. However, the overloaded plane refused to leave the water without a helping wind, and valuable hours were

spent "hunting for a breeze." As additional safeguard when it became evident that landfall would not be made until midafternoon, the course was laid not directly to Julianehaab but to the headland, Nunarssuit, sixty miles to the northwest, so that there should be no doubt as to the direction to turn in order to reach our destination.

Shortly after the Labrador coast had disappeared behind, we encountered fog and rain. It seemed useless to deviate from the course in search of better conditions, and I descended low—250 feet—where Wilson caught occasional glimpses of the water for drift readings. Three hours offshore the fog disappeared, and we had clear air beneath the clouds the rest of the way. The ocean crossing was not dull; Wilson kept up a continuous conversation (in code) with the radio operators at Cartwright, Resolution Island, and Julianehaab and overheard signals from Grierson, the English flier, who was in the vicinity of Godthaab. Halfway across messages began to come in from officials at Julianehaab, among them invitations for dinner, which we optimistically accepted. We also arranged to refuel the ship on arrival.

Greenland, West and East

Five hours and forty minutes after we had left Cartwright two icebergs appeared. Three minutes later we became aware of a dark mass ahead, which, as we watched, resolved itself into the definite contours of land. At the same time the curtain of clouds ended overhead, and we came out into warm sunshine, with the magnificent coast of Greenland spread out in front—the coastal islands rising steeply nearly 4000 feet; behind and higher, jagged mountain masses; and at a great distance, like a soft mantle of white, the icecap.

We climbed to 5000 feet and turned toward Cape Farewell, hoping to recognize islands and fiords from comparison with the charts. It was confusing, and finally we resorted to a determination of the direction of the coast line itself by measurement from the sun's azimuth. The true bearing proved to be 102°, and on the chart this line fitted the coast only between Nunarssuit and Julianehaab. Landfall had been made 25 miles to the left of the course, near Ivigtut, and we were in fact proceeding toward our goal.

Some twenty miles west of Julianehaab a fog layer was encountered. We flew to the estimated position of the town, but no openings appeared, and regretfully—those dinner invitations!—we were compelled to turn back. A half-hour's search brought to view a cluster of three or four houses facing a tiny harbor from which a narrow channel led to a wide fiord. We landed in the open and were greeted by the sight of six Eskimo kayaks in a race for the plane. Their approach was so rapid that I cut off the ignition switches and drifted lest they run afoul of the propeller. It was a needless precaution, for the Eskimos

FIG. 6

FIG. 7

FIG. 6—Looking towards the north at Bear Head, west coast of Newfoundland. (Aug. 21, 1934; 17:48; 1680 ft.)

FIG. 7—Table Mountain, southwest corner of Newfoundland. (Aug. 21, 1934; 16:30; 1280 ft.)

FIG. 8

FIG. 9

FIG. 8—On the east coast of Greenland. The entrance to Prince Christian Sound looking towards the west. (Aug. 29, 1934; 13:04; 4200 ft.)

FIG. 9—View of Julianehaab, Greenland. The radio station is at the top of the hill to the left. (Aug. 28, 1934; c. 1500 ft.)

pulled up skillfully about fifteen feet off, their boats pointed in a neat row toward the plane. We held up the chart and called off names of settlements and islands in the vicinity, and the natives responded by pointing with great certainty in the direction of each spot named. For their part they had only one question: the leader came close and asked, pointing to us, "Lindbergh?" We shook our heads, and he backed off in disappointment.

When the motor was started, the best sprinter of the group pushed his kayak up to a position just ahead of the floats, to lead us in through the tortuous channel between rocks and icebergs. The entire village of perhaps fifty people was on a rock that served as a pier. They were all smiles and eager to help, and I was soon taken into a tiny one-room house and seated opposite its owner, obviously the schoolteacher. Neither of us knew the other's language, but he drew out a blackboard and some chalk and in easy script began the introductions. It seems we were in Qeqertarssuaq and he was Isak Abelsen. Others of the family were "met," and then Isak began a lesson in Greenlandic geography. Behind his chair hung a bookshelf of volumes printed in Danish, from which he drew an atlas and turned to a map of this sector of the coast. The detail was much better than on any of our charts, and with his stubby finger the teacher traced the proper route to Julianehaab: across the wide fiord where we had landed, through a narrow, twisting channel to another open area, and so on. Of course, he was giving the kayak route, and not the path that we would fly, but, knowing the amazing ability exhibited by Labrador Eskimos with whom Dr. Alexander Forbes had come in contact,[2] I was certain that had we needed a guide no better one could have been found.

Outside the house people were waiting patiently to bring the duffel ashore; when we handed it to them piece by piece, it disappeared promptly in the crowd, to reappear in a neat pile in our lodging. We did not bother to lock the airplane cabin; these friendly Greenlanders were neither impolite nor intrusive, and throughout our visit we felt the value of their quiet and intelligent assistance.

Weather was good next morning, and a flight of three-quarters of an hour brought us to Julianehaab and the cordial greetings of the governor of the colony, the manager of the radio station, and several hundred natives. The engine was checked over, and, bearing in mind the lateness of the season, we continued our flight next day. Again quiet water balked the plans for an early start. A direct crossing of the Denmark Strait to Reykjavík could not be accomplished before sundown. Therefore, after rounding Cape Farewell it seemed best to turn toward the nearer harbor of Angmagssalik. The following radio messages, taken from the log, explain the change.

[2] Alexander Forbes: Surveying in Northern Labrador, *Geogr. Rev.*, Vol. 22, 1932, pp. 30–60 especially p. 52.

Plane (1640 GCT): "Weather please?"

Angmagssalik: "Here fine weather, clear, calm, and very fine landing conditions on the Fiord—your position please?"

Plane: "Position ten miles north C. Discord."

Angmagssalik: "When can we expect you at Angmagssalik?"

Plane: "Arrive Angmagssalik approx. 2115 GCT. What time does sun set? Have you any aviation gasoline?"

Angmagssalik: "OK if 2115 GMT[3] OK. Sunset about 2200 GMT. Think gasoline but better ask governor; will do so. Can I do anything for you? Just tell."

Plane: "We left Julianehaab with thirteen hours' fuel and expect to reach Reykjavík safely without addition. Stop. Would appreciate knowing whether any is cached with you, however."

The flight was continued for 3 hours and 40 minutes along the ice-ringed eastern shore; on approaching Angmagssalik:

Angmagssalik (2021 GCT): "Fine landing conditions on the fiord, much better than anywhere; Grierson came here."

Plane: "Can we land in the harbor rather than the fiord?"

Angmagssalik: "Harbor is too small for landing even if free from ice . . . do you see the big fiord going nearly south to north? . . . Sermilik Fiord. Some miles east of the mouth of Sermilik is Angmagssalik. You are flying a bit to south. Do you see fiord with a very small entrance? You will see a flag on a hill—look for you, can't see you now."

It is now evident we have passed Angmagssalik; we turn back.

Angmagssalik: "We saw you—Please keep in direction and you will cross us. Do you see island about 65 30 and 37 west? It is Cape Dan. Do not mistake for Angmagssalik."

We searched intently for the settlement, and suddenly Bob spotted a column of smoke and saw a ship, then some houses. We landed near by in a narrow lane between icebergs. The ship at anchor here proved to be the *Pourquoi Pas?* under the command of Dr. Jean Charcot, who soon came alongside the plane and helped direct the mooring, while explaining the movements of icebergs in this bottle-neck fiord, with its 20-foot tides. We dined on board and met the other members of the scientific personnel of the *Pourquoi Pas?*, four of whom were to winter ashore for study of various phases of Eskimo life in this curious little colony. One, a physician, had brought with him X-ray equipment to verify or disprove the suspicion that tuberculosis is making its way into this group of Eskimos.

After leaving Angmagssalik next day we met with a 50-mile northeast gale that, a little more than an hour out, forced our return to the fiord. The experience, however, was reassuring in its way. The lateral drift had been extraordinary, 30° to 35° at 120 miles an hour, yet we were able to return exactly on course to Angmagssalik.

[3] Greenwich Mean Time is measured from noon. Greenwich Civil Time, measured from midnight, is now more generally used. However, it is a habitual error among many mariners to confuse the terms and to reckon GMT from midnight. The Angmagssalik operator, under this false impression, is questioning our use of the term GCT.

FIG. 10—The southern coast of Iceland at Portland, looking northward to Myrdalsjökull. A few minutes after this picture was taken a heavy dust storm was blown up from the Myrdalsandur. (Sept. 3, 1934; 09:24; c. 800 ft.)

During the night of August 30 the fiord filled with ice, making a take-off difficult the following morning. The storm, slightly abated, was still driving across the strait. Again I took the choice of staying low for drift indications instead of going high in search of clear air. Low it was, 150 feet and even less, and the drift again proved to be very great. We passed beyond the ice, but for a long time solitary wandering bergs loomed out of the mist, their tops lost in the clouds. After four hours, most of it instrument flying, a faint light streak appeared ahead, and, since there had been no sun observations for compass verification,[4] I pulled up through the clouds and at 2000 feet came out in the clear.

While Wilson was completing his observation the clouds began to fade away, and soon, as a thin dark line, the coast of Iceland appeared ahead. By radio we described a distant snow-capped peak to the Reykjavík operator and learned that it was Snæfellsjökull, which gave us bearings toward Reykjavík. The Icelandic capital was reached after seven hours of flying; the storm, whose severity may be gauged by the Jan Mayen report of an 11-force wind, had caused us a severe setback.

[4] The permanent magnetization in airplanes constructed of steel, for which correction is made with accessory magnets when the compass is "swung," may change rapidly during flying. This occurs most prominently when a relatively constant heading of the ship is maintained over many hours; an error of 10° developed during the 10 days between New Haven and Reykjavík. The same phenomenon occurs to some extent with steamships at sea; on a crossing of the Pacific the magnetic compass often develops an error of 3°.

ICELAND AND THE EUROPEAN FLIGHTS

The city of Reykjavík proved delightful, and we toured the neighboring countryside as well. Not least interesting was a visit to the wireless station to chat with the operators who had given assistance throughout the stormy crossing. The equipment there was excellent and included a valuable special service for small fishing vessels. For $25 a year the government rents them portable 10-watt phone sets with an operating range of 200 miles. Constant radio watch is kept on the part of the coast along which the vessels are fishing: herring on the north coast in the summer, cod on the south in the winter. A skipper in distress can summon assistance by merely turning a switch and talking into an ordinary telephone.

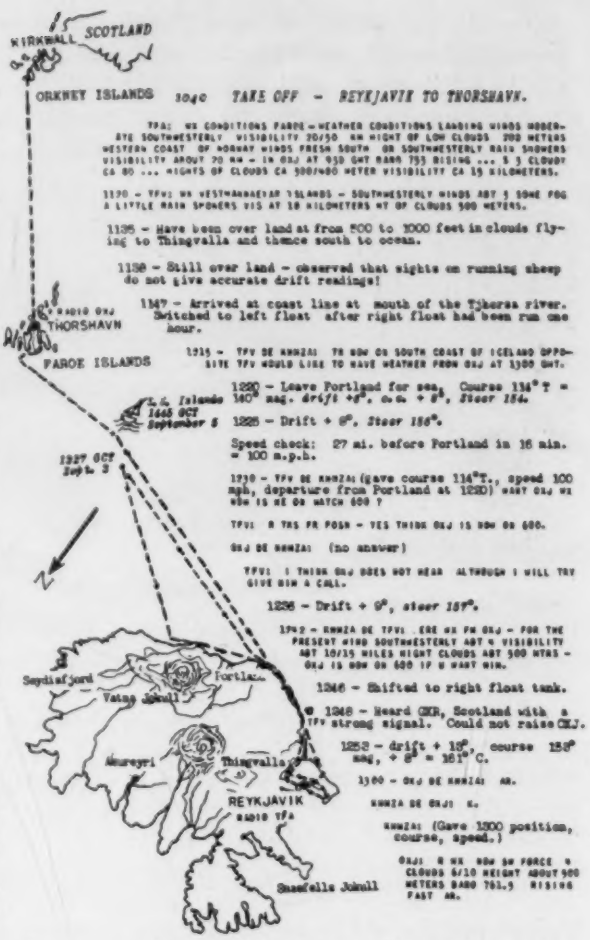

FIG. 11—A typical page (reduced) from the journal of the cruise.

Iceland was as hard to leave as it had been to reach. On our first attempt, September 3, we turned back a hundred miles short of the Faeroe Islands after being notified that dense fog had developed ahead. The additional time in Reykjavík gave opportunity for a visit to the leper hospital—fortunately an almost unnecessary institution now. It was then, too, that the airplane was christened with the Greenlandic name suggested by the governor at Julianehaab, *Asulinak*, meaning "I'll take a chance" or "Why worry?" There were times later on when we wished something more conservative had been chosen!

On the 5th we set off again, bearing a packet of letters that the postal authorities had hastily stamped "Air mail, Reykjavík to Edinburgh." Our visit had coincided with the issue of a set of Icelandic air-mail stamps. After a short struggle with a thunderstorm, which drove us inland as far as Lake Thingvalla, the weather cleared, and we left the southern coast of Iceland for the hop oversea to the Faeroe Islands. A six-hour flight brought us to this island group whose fantastic charm is eloquently described by Dr. Charcot in his "Voyages aux Iles Feroë" (1934). Landing was made outside the breakwater at Thorshavn in the half gale that is characteristic of the Faeroes when fog is not shrouding their slopes (for photograph of typical slopes see Figure 3).

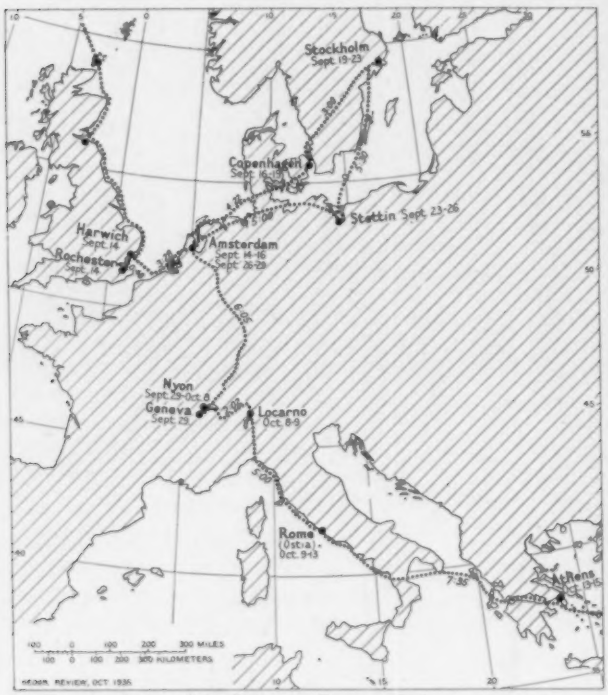

FIG. 12—Stages of the flight over Europe. Scale: 1 : 30,000,000.

The provost and assistant provost guided us on a tour through the quaint little town, including the hospital and a fine museum of Faeroese industry. The exhibits are excellently arranged around the weaving arts and fishing. The great green slopes along which we had flown support about 100,000 sheep and many cattle. Cod fishing, too, is carried out on a large scale, both in neighboring waters and in distant Greenland. Its importance to Faeroese trade is such that the "Parliament" of the islands is sometimes held in Spain, the chief export market!

From Thorshavn it was an easy three-hour run to Kirkwall, capital of the Orkneys, and after lunching on the good island mutton we pushed along to Edinburgh, happy at completing the first stage of the journey. The halt in Edinburgh was the first of a series of visits to European neurosurgical clinics. Five weeks were thus spent, during which international formalities proved surprisingly easy. The

several flights were themselves full of interest, especially the crossing of the Alps, something rarely done in a seaplane. We must, however, pass over this part of the journey without further comment.

The Near East

I take up the narrative with our departure from Athens on October 15, eastward bound for Cyprus. Soon after leaving Phaleron Bay

Fig. 13—Famagusta, Cyprus. The castle and the cathedral of St. Nicolas stand within the fortifications, which were remodeled by the Venetians after 1489. (Oct. 18, 1934; 08:00; c. 500 ft.)

we dipped low over the Temple of Poseidon,[5] its lovely white pillars surmounting the cliff that forms the southeast corner of Europe (Cape Sunium), and struck out over the route of the early Greek sailors in their excursions into unknown seas to the east. In short space we passed over Zea, Thermia, and Syra—set like crude dark stones in a background of brilliant blue—and settled back for a day of peaceful flying. We took pains to avoid the Dodecanese and Rhodes; Italy does not welcome foreign airplanes over these fortified outpost islands. So too we gave Cape Krio wide berth, for an unauthorized visit to Turkish territory is apt to have an unfortunate ending. It was perhaps an hour east of Rhodes that I realized that something unusual lay ahead. Wilson had complained of severe static since the take-off, and now, with a great formation of clouds in sight, he called out that the antenna was loaded with upwards of 30,000 volts so that he had to reel in and give up altogether. The storm had a peculiar blue-gray appearance, like a wall that ends in neither ceiling nor floor. I had to fly by instruments, since there was no indication of horizon even though we were still in clear air. Lightning flashed; rain patches began to show; the air roughened. I dodged

[5] See E. C. Semple: The Templed Promontories of the Ancient Mediterranean, *Geogr. Rev.*, Vol. 17, 1927, pp. 353–386, especially Figs. 1 and 7.

first to the left, toward Turkey, but the way was solidly blocked; then back to the western edge of the storm, zigzagging southward toward the Egyptian coast, while Wilson plotted the changing route as best he could. A strong head wind struck us, and at the same time a dark curtain of rain appeared at the left. It was the "windshift line," and after a bumpy transit we gained the opposite side and turned back toward Cyprus, aided by clear air and a following wind.

Troubles were not over, however, for Cyprus has no harbor for seaplanes except at Famagusta, and there are only one or two possibilities on the Syrian coast. The storm was moving east or southeast, and we must expect it to pass over any anchorage we might choose, and very soon after landing! We skirted the southern shore of Cyprus, at the last cutting over land through clouds of dust. The front of the storm was al-

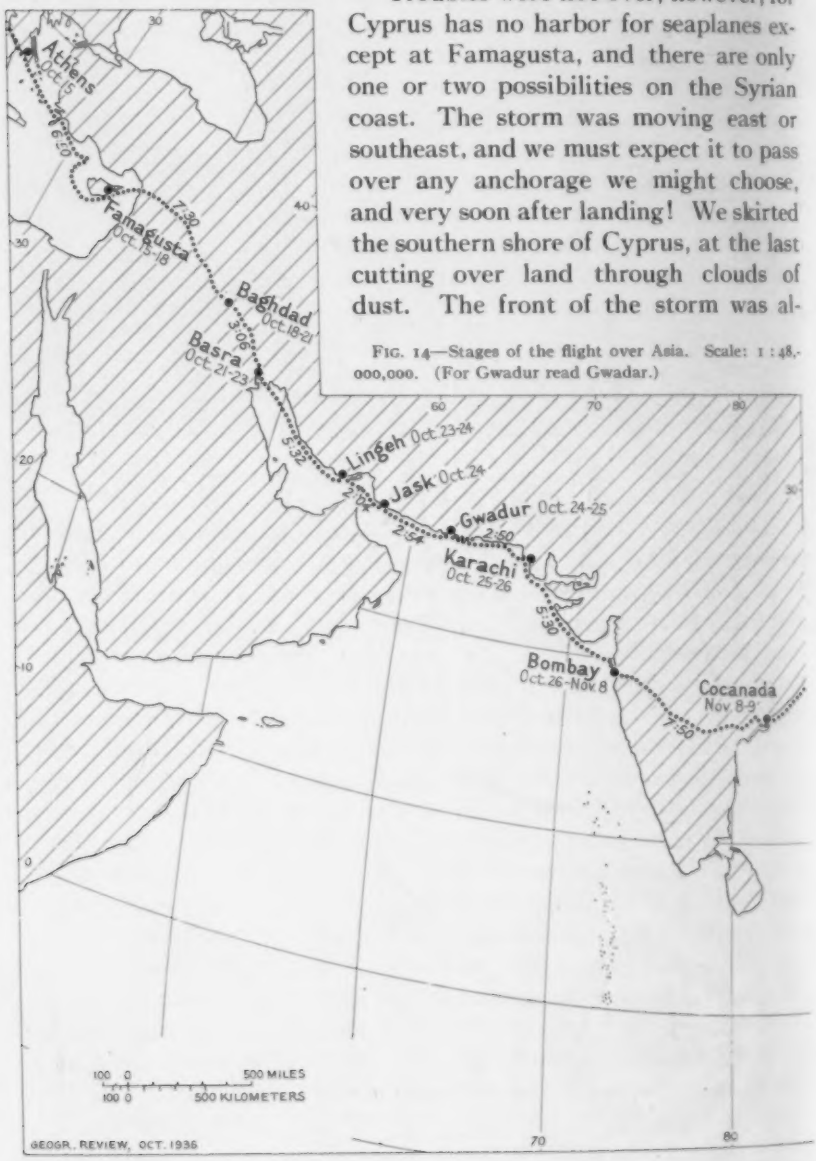

FIG. 14—Stages of the flight over Asia. Scale: 1 : 48,000,000. (For Gwadur read Gwadar.)

ready at Famagusta and the country beyond hidden in a black wall of rain. I found the harbor small, full of craft and buoys, and obstructed by several reefs. No sooner had we landed than the heavens opened in the worst downpour of recent years in the island. The town rain gauge recorded 0.83 inches of rain during 35 minutes.

A few days were spent in this fascinating medieval town. Then on October 18 we started on the long journey to India, entering the Asiatic mainland over the mouth of the Orontes, passing by Aleppo, and following down the Euphrates, with stops at Baghdad and Basra. We skirted the barren eastern shore of the Persian Gulf, where the cabin thermometer registered 110°, and descended for the night at Lingeh. On going ashore we were astonished to find this a deserted city. From a flourishing community of 40,000 people, Lingeh has declined to a few thousand. The people, we learned, depended on the pearl industry, and the oysters have recently transferred their habitat to the other side of the gulf. The pearl market is now in Bahrein, although it is not ten years since Lingeh was at the peak of its glory. Now there is no hotel, no bank, no telegraph, no radio, no electric plant—just 5000 forlorn people living in the shell of a great city.

We had expected to find Jask a port of some size because of its commanding position at the entrance to the gulf. In fact it is a mere collection of houses defying the rigors of a waterless desert. The harbor is an open roadstead slightly protected by a curve in the shore.

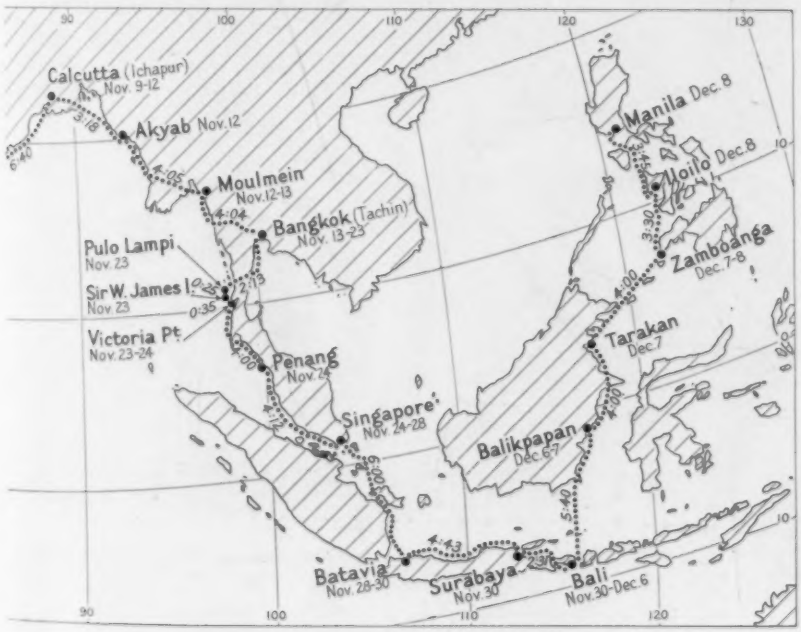

FIG. 15

FIG. 16

FIG. 15—Looking southwestward over the mouth of the Orontes River. Note the sharp line between the delta and the clear Mediterranean waters; also the terraces along the favored northern slopes of the river bank. (Oct. 18, 1934; 09:55; 4000 ft.)

FIG. 16—Looking eastward over Aleppo, Syria. (Oct. 18, 1934; 10:49; 5100 ft.)

FIG. 17

FIG. 18

FIG. 17—The Baluchistan coast 15 miles west of Gwadar. (Oct. 24, 1934; 16:25; c. 1000 ft.)
FIG. 18—A group of camels being led along the shore from Gwadar. (Oct. 1934; 17:36; c. 200 ft.)

We landed, anchored, and had lunch before resuming the flight along the Baluchistan coast—a long stretch of barren, sandy foreshore broken by magnificent cliffs and headlands. While flying along this coast of a late afternoon one feels a sense of exhilaration: as in all barren, eroded regions, the deep shadows from the setting sun intensify nature's fantastic architecture. Just at the end of the run, Gwadar, we came upon a train of camels plodding slowly across the beach, their shadows flung out many yards to the east.

It had given us something of a start to notice on the map that Gwadar bore the same color as Muscat and the label "to Oman." Having made no overtures to Arabian authorities, we radioed ahead after leaving Jask to ask if we could land. The operator assured us in good English that Gwadar was a free port, that we were welcome there and should have dinner with him; and it ended by our spending the night on the cool porch outside his transmitting room. Near Pasni the early morning fog characteristic of this coast compelled a return to Gwadar, but by noon it had blown away, and we resumed our flight along the baked sand cliffs to Karachi. To make this journey by camel caravan must be an exploit to be proud of! Some fifty miles from Karachi, well out in the Arabian Sea, we came over vast areas where the water was streaked bright vermilion, due we learned subsequently to organisms known locally as "whale food."

Karachi to Moulmein

The flight from Karachi to Bombay was hot and bumpy, and the dull, flat country made the trip tedious. The delta of the Indus is an amazing wilderness, the largest expanse of mud that I have ever seen, and one can readily sympathize with those early Greek navigators who ran afoul of the Great Rann of Cutch. The Kathiawar peninsula, last remaining stand of wild lions in India, likewise showed a flat coastal strip, but with occasional farms, and it was good to see anything growing again! It took an hour to cross the Gulf of Cambay, and shortly afterward we could see Bombay crowded within the narrow confines of its island—an impressive city, with a tremendous system of docks and shipyards and important buildings lining a maze of crooked streets.

Here we met with enforced delay. Bad weather shut down over the southern part of the Indian peninsula and then extended up both coasts. A storm was raging off Konkan, with high winds and rainfall of a quarter of an inch to four inches a day, and in its wake appeared the first signs of the northeast monsoon. The delay, however, was not unwelcome, for it gave me the chance to look into the medical problems of a great tropical city. Malaria forms the chief concern, and the prevention commission has made amazing progress in its

control. But there are other worries: a pointed editorial in the *Times of India* (November 2) drew attention to the threat of an even more serious epidemic disease, yellow fever. Two of the three conditions necessary for the existence of yellow fever are at hand: an abundance of the *Aëdes* mosquito and a susceptible population of human beings and monkeys. Now it is feared that the speed of aerial transportation may some day bring about the introduction of the third element, the yellow-fever virus, from its home in western Africa.

The onset of the monsoon forced a change in plans. It now was impossible to round the southern tip of the Indian peninsula with the seaplane; instead a route overland to the Bay of Bengal was chosen. The course was set first to Poona, and we climbed above the Western Ghats just after sun-up one morning. The mountains are not high, 4000 feet at the summit, but they made a lovely sight as the light began to creep up their deep ravines. Soon the railroad appeared from the left, electrified all the way to Poona. Just beyond the divide, which lies only 30 or 40 miles from the coast, two large reservoirs have been constructed; by means of a tunnel they supply drinking water to Bombay. Like all wise cities of the tropics, however, she chlorinates the water heavily before serving; and, like equally wise tourists, we boiled it in addition!

As the Ghats slipped behind, we debated our subsequent course. India has been crossed by seaplane on very few occasions, and, since no one had followed this particular route, no experience was available as a guide. The straight-line course to Cocanada lay over a semiarid plateau, but by deviating southward we could follow the Bhima and Kistna rivers to the east coast. The streams, while too shallow for seaplane operation, offered a greater margin of safety for forced landing, but the detour would add nearly a hundred miles to an already long journey. In the end, the valley route was chosen.

The country was much of a type. It is the area of the Dekkan lavas, with bare, undulating plains and flat-topped hills. In spite of its semiarid nature, however, it is cultivated throughout, and its people, at least those of the lower Bhima, pay taxes to "the richest man in the world," the Nizam of Hyderabad. Near the Kistna junction a change occurs; here granite rocks have been weathered into characteristic tors and bosses, some of them simulating fortified towns. The towns themselves are often walled and moated, with a central fortress.

An unexpected danger appeared in the shape of buzzards in great numbers. They paid no attention to the flight of the plane, which they might easily have wrecked by dashing against a wing or propeller. We had to be constantly on the lookout against them. Meanwhile the Kistna River below zigzagged into a deep gorge, lined with jungle as far as one could see. In 150 miles only two or three habitations

FIG. 19

FIG. 20

FIG. 19—Farms on the Kathiawar peninsula, looking northward. (Oct. 26, 1934; 11:01; alt. 2500 ft.)
FIG. 20—The Western Ghats, Konkan, 40 miles east of Bombay. The mountains here are about 4000 feet high. (Nov. 8; 07:30; c. 4500 ft.)

FIG. 21

FIG. 22

FIG. 21—Koregaon, a small town of the upper Bhima River, about 75 miles from Bombay. (Nov. 8, 1934; 10:10; 4500 ft.)

FIG. 22—Gadwal, an ancient fortified town of Hyderabad. (Nov. 8, 1934; 11:24; c. 4000 ft.)

appeared, and very rarely trails. The jungle was fairly open and did not look dangerous, but the river ran a swift course in its gorge, and I was rather glad to see it spread out above Bezwada, where its delta is confluent with that of the Godavari.

The sight of the great delta lands aroused our particular interest, for this coastal belt holds one of the most concentrated populations in the world. The fields were bright green with rice paddy and dotted with giant palms and mangroves. Irrigation was consistently carried out. The most surprising feature was the frequency of the towns, perhaps one for every square mile. Population estimates are difficult unless one knows the standard of living, but at a guess these villages house from 1000 to 5000 persons, and some as many as 50,000. We followed the Godavari downward from Rajamahendry, making note of suitable areas for landing, but fortunately found conditions excellent in the roadstead at Cocanada.

The first portion of the flight from Cocanada to Calcutta continued to hold much of interest—for hundreds of miles not a 50-yard stretch of beach but had its group of fishers, who presumably live back in the thatched huts of the paddy country. Vizagapatam appeared to be a port of some consequence, and the seaside resort of Puri was amusingly reminiscent of our own Atlantic City. We picked up a weather report: "Cyclonic storm apparently centered about one hundred fifty miles southwest of Akyab. . . . " It was evident we should have a steadily increasing northwest, and then a north, wind to face. The air was extremely rough and hot; hotter still when I opened up to overcome the wind handicap. There was an hour across a big gulf—a rather welcome hour, for here it smoothed out a little—and then we started up the Hooghly River. Great dikes had been thrown up to keep the stream under control, and on each side the delta was inhabited and cultivated to its last inch. Calcutta proved surprisingly white and built-up as we passed in toward the anchorage at Ichapur, twelve miles upstream.

The Calcutta days were busy ones: a call on Dr. L. L. Fermor, Director of the Geological Survey of India, who had arranged for our photographic permission; a visit to the Asiatic Society, to learn something of the native tribes in Malaya, which we were soon to enter; a day at the School of Tropical Medicine. The last was a scene of tremendous activity. It is the foremost research center in tropical diseases. My few hours gave hardly time enough to walk through, and I could only seize upon the most interesting points for eager if brief discussion: malaria, leprosy, kala azar, epidemic dropsy, and drug addiction.

There was still a mist around Calcutta when we took off on November 12. The delta land was wet in paddy, and there were many stretches of impenetrable swampy jungle. We swept across these

FIG. 23

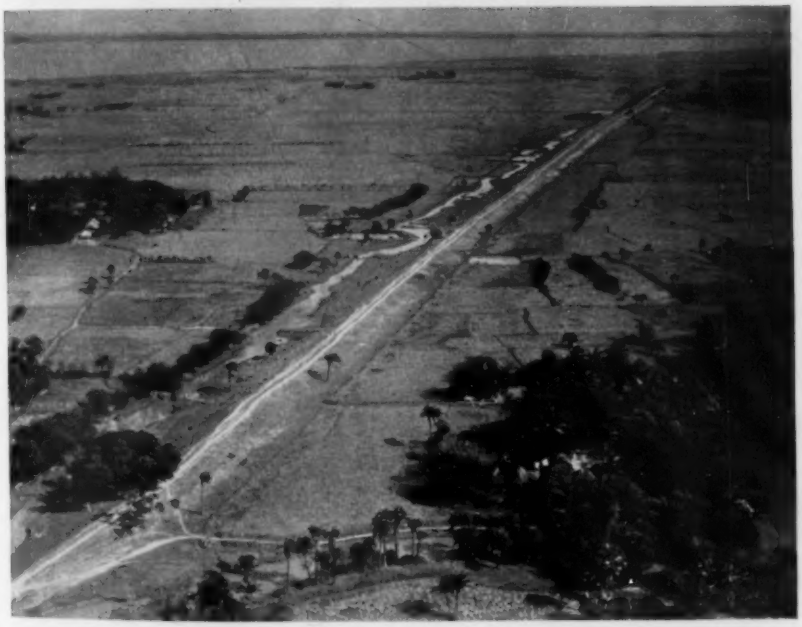

FIG. 24

FIG. 23—A typical village of the densely populated coastland southwest of Vizagapatam, India. The population depends mainly on rice, the coconut palm, and fishing. (Nov. 9, 1934; 08:17; 250 ft.)

FIG. 24—The Hooghly River is in the background; a dike, topped by a road, runs diagonally across the picture; rice fields, coconut, betelnut, and banian trees. (Nov. 9, 1934; 15:36; c. 400 ft.)

at a steady pace and passed out to sea over shoals opposite one of the mouths of the Brahmaputra. After checking position on a lightship far out in the bay, we took up a new course for Akyab and soon had the first close view of the rocky shore that was to be our guide for thousands of miles. It looked curiously friendly—a bright-green paddy that seemed like a sprinkled putting green, sturdy low hills covered with darker green trees, and a wide beach, clean, neat, and healthful. Of course, nothing of the sort! It is filled with devilish animals—malarial mosquitoes, poisonous snakes, crocodiles, tigers, and elephants; and its inviting waters are foul to drink.

We spent no more than twenty minutes refueling at Akyab and then sped with opened throttle toward Moulmein in a race with darkness. North of Gwa we turned inland and skirted cloud-laden mountains at 4000 feet, to come out on the green Irrawaddy delta. Rangoon was elusive but appeared finally. Its faithful radio operator, like that other friend at Julianehaab, never left us and performed a multitude of services. Had conditions seemed favorable, we might have stopped at Rangoon, but the heavy river traffic in a swirling six-knot current looked as dangerous as Von Gronau had reported, and we passed by. It was an impressive sight, however, with its pagodas lovely against the setting sun. In the other direction the outlook was less pleasing; Moulmein lay 80 miles east, and all was black except when lightning flashed in the hills beyond. When we arrived there half an hour later, the famous Kipling town was only a twinkle of lights. We circled once and landed on the invisible surface of a quiet river.

Next morning the city could be seen in all its beauty. The "old Moulmein Pagoda," straddling a low hillcrest near the Ellen Mitchell Memorial Hospital, presented a jumble of green and gold turrets around a central cone. The rooftops of the town added much to the picture, and there were at least a dozen smaller pagodas besides.

Siam, Malaya, and the Dutch Indies

The flying problem between Moulmein and Bangkok centered on how best to cross a mountain range of unknown elevation and reach a big river on the other side. Should we leave the coast at Ye or continue to Tavoy? I began to climb opposite Foul Island, but ascent was slow because of the east wind pouring down the slopes. After a short reconnoiter an updraft was located, and on this we rose to 4000 feet, but it was far short of the necessary altitude. Twice I started inland, only to return to the friendly hill and climb higher. Finally, with 9000 feet, it was possible to surmount both the mountain peaks and their banner clouds.

We crossed perhaps three main ridges near the headwaters of the Tenasserim River and then descended through clouds into the valley

FIG. 25

FIG. 26

FIG. 27

FIG. 25—A load of hay or rice being brought into Calcutta. The School of Tropical Medicine has shown that the widely distributed disease of epidemic dropsy can be eliminated when rice is kept from dampness during transportation. (Nov. 13, 1934.)

FIG. 26—Sunset over Rangoon and the traffic-filled Irrawaddy River. (Nov. 13, 1934; 17:60; c. 2500 ft.)

FIG. 27—Panoramic view of a minor midday tropical storm off the Malay peninsula near Dindings. (Nov. 24, 1934; c. 1000 ft.)

of a river that we supposed would lead to the Gulf of Siam. There followed an hour and a half over the worst jungle I have ever seen; by contrast the Isthmus of Tehuantepec looks like a fairway. The deep, swift stream, swollen with heavy rains, seemed to be painfully fighting back the vegetation that threatened to overwhelm its very banks. For a long time there was no sign of human life; we spotted first a raft of teak logs, then another, and then a small hut built on the river-bank. There were no trails, or if any exist, no trace could be seen from above. Farther on, rafts were run in tandem, steered by an oar at each end. An increasing number appeared, then a tiny village, and finally we came out on the broad, level valley of the Menam.

FIG. 28—A boat of the Mawkens, sea gypsies, at Pulo Lampi, Mergui Archipelago. (Nov. 23, 1934.)

After the mountains the alluvial lowland seemed a lazy place, and we loafed along downstream until we reached a railroad which led us to Bangkok. At Nakon Pathom, one of the famous pagodas, a dutiful detour was made, and soon Bangkok itself was reached. From the air this was an inspiring sight, chiefly because of its many brightly ornamented temples, or wats. There was a good deal of small shipping in the river, which enters the sea twenty miles below, and across it was a new lift bridge. We turned back across the swamps to Tachin, a thriving town near the mouth of the river of the same name and some twenty miles from Bangkok, with which it is connected only by railroad. Siam is virtually roadless. Of the million inhabitants of Bangkok probably four-fifths live in the broad belt surrounding the city, and their homes can be reached only through the system of canals. From the air I had supposed this was a belt of suburban truck gardens, and such it may be considered, for each householder has his coconut and betel-nut trees, and short rows of vegetables planted in earth thrown up a little above the level of high tide.

Both members of the "crew" caught cold in Bangkok—as a result of electric fans and refrigerated theaters—and further travel was not resumed for ten days. From this point onward to the Philippines several routes lay before us. We chose to continue southward following the east (Siamese) shore of the Malay Peninsula for some distance. It was an irregular coast line, scalloped in fine beaches and

intersecting rocky headlands. Towns and villages were not infrequent, especially where the Bangkok-Singapore railroad lay close to the shore. One good airport was passed. The hinterland was a solid jungle, leaving from four to fifteen miles of coastal fringe under rice, coconuts, and rubber. In the foothills were numerous tin mines. Near Bangspan a long streak of clouds intersected the coast, stretching across the peninsula toward the southwest. We rose to cross to the western side over a jungle as thoroughly forbidding as the region we had seen farther north. We learned subsequently that it probably has never been traversed on foot in all the distance from near Penang to the neighborhood of the Chinese border, 800 miles to the north. Once only did we see a clearing: it reminded us forcefully of the legend that aboriginal tree-dwelling men are to be found in these fastnesses.

FIG. 29—A group of some thirty Mawken boats drawn up on the jungle shore at Pulo Lampi, Mergui. (Nov. 23, 1934; 02:00; c. 500 ft.)

We breathed more freely when the Mergui Archipelago made its appearance beneath us. Here was our opportunity to look for that peculiar people, the so-called sea gypsies, the Salones or Mawkens, of whom tales had been told us by officers of the Royal Indian Navy in Bombay. The islands of the archipelago are the tops of ridges rising abruptly out of the ocean and extending for 200 miles from Mergui to Victoria Point. Some are 30 miles long, others so small that they look like umbrellas perched on a wave. One, St. Matthew, rises to

FIG. 30

FIG. 31

FIG. 30—A scene in the populous and productive island of Bali. The fields are planted in rice interspersed with coconut palms. (Dec. 3, 1934.)

FIG. 31—A small island of the Jolo Archipelago, Philippines. The houses are built over the water on stilts; the population lives on fishing and coconuts. (Dec. 7, 1934; 15:25; c. 1800 ft.)

nearly 4000 feet. Nearly all have good beaches on some exposure, and once or twice we saw a beach without an island! The entire group is covered with heavy jungle, and the dark green of the trees, the white beaches, and the blue water make a paradise for the seaplane flier. Pulo Lampi (Sullivan Island) appeared as a beautiful sickle-shaped

FIG. 32—Salina Cruz, Oaxaca, a harbor created at great cost and now virtually abandoned. Note the silting. (Jan. 17, 1935; 11:30; c. 2000 ft.)

island of some size. We crossed to the western side and dropped low to scan its shores. Suddenly I saw a group of boats hidden in a small inlet—six of them—covered over as our informants had described the Mawken boats.

We landed immediately and went ashore. The boats were dugouts enlarged by a split-bamboo superstructure that seemed virtually waterproof. A decking, which extended across nearly the entire length of the craft, was littered with dishes, poles, matting sails, oars, clothing, and fish. There was also a baked mud fireplace. Water was carried in large jugs, two to each craft, holding about twenty gallons each. The people were timid but did not run away, largely because of the reassuring presence of Mustapha, a Malay tin miner who joined us. There were men, women, and children in the same boat, about thirty people in all in the half dozen craft. They were of our own size and very dark, with slightly sloping foreheads and coarse, matted black hair, worn long by most of the men. Dress for both sexes consisted of a skirt gathered between the knees, though the

FIG. 33

FIG. 34

FIG. 33—The beautiful harbor of Acapulco, deep, protected, encircled by a fine beach. Acapulco is now connected with Mexico City by a daily airplane service. (Jan. 16, 1935; 14:00; c. 400 ft.)

FIG. 34—The Tehuantepec Pass, Oaxaca. The interoceanic railroad winds through the rough defile. The airline distance from the Atlantic to the Pacific is here about 140 miles; it is possible to cross with about 1500 feet altitude. (Jan. 17, 1935; noon; 4000 ft.)

FIG. 35

FIG. 36

FIG. 35—Puerto Angel, Oaxaca, a fishing village on an isolated section of the western coast of Mexico. The small harbor, flanked by high jungle-covered ridges, affords practically the only seaplane anchorage between Acapulco and Salina Cruz. (Jan. 17; 10:20; c. 500 ft.)

FIG. 36—Carmen, Campeche, at the entrance of the Laguna de Términos, is a shipping port for the chicle, hemp, mahogany, and logwood of Yucatan. In recent years there has been an extensive planting of bananas, but the port has lost its former prosperity. (Jan. 17, 1935; 15:50; c. 200 ft.)

woman's sometimes hung free. We learned later that the Mawken people also engage sporadically in mining, going into the hills to scratch out enough tin to trade with the Chinese junks for rice and cloth.

Continuing toward the southern end of Pulo Lampi, we came upon a larger group of the sea gypsies, with fifty or seventy-five boats drawn up on shore. No stop was made here, but a few miles farther we found still another group of perhaps half a dozen boats on the western side of Sir W. James Island, the occupants of which were engaged in fishing and diving.

Leaving the islands, we flew back to Victoria Point, on the southern boundary of Burma, a picturesque settlement strung out between a muddy beach and the crest of a low hill. The flight thence to Singapore was made through a series of tropical thunderstorms that drove us off our course at times and yet gave very little real trouble, for generally we could fly through their fringes. The vegetation of the peninsula did not change much as far as Penang. From that point to Singapore the wild country has been tamed and given over to rubber plantations, laid out with the regularity of carefully kept gardens. Coconuts and fruit are also seen, but the bulk of the agriculture is in the hands of the great rubber planters.

Blind flying is always a dangerous practice in unfamiliar territory and especially so over an archipelago such as the East Indies. Therefore, when it became impossibly thick on our course from Singapore to Batavia, I turned sharply eastward into the Java Sea until we were outside the long chain of islands, to quarter a way back through the storm. It was a lucky maneuver, because directly in our path had stood Lingga Island, rising several thousand feet into the air. We could see it from the south side after we had turned back on the course for Banka Island and the Sumatra coast.

FIG. 37—Stages of the flight from Vancouver to Havana. Scale of map 1 : 40,000,000.

It was rice and palms most of the way from Batavia to Surabaya, where our Javan journey was broken for lunch. Then two hours of storm dodging as we continued eastward. At Bali we lingered nearly a week, unable to tear ourselves away from this enchanting isle. Finally on December 6 we took off from its dredged harbor for the Philippines. A 300-mile crossing of the Java Sea brought us to Borneo, whence our route followed the swampy fringe of that island's east coast to Balikpapan, the seat of the great Dutch oil refinery. Next day a refueling halt was made at Tarakan, also an oil center, and then with considerable excitement we once more entered United States territory in the Jolo Archipelago, whence two impatient stages brought us to Manila.

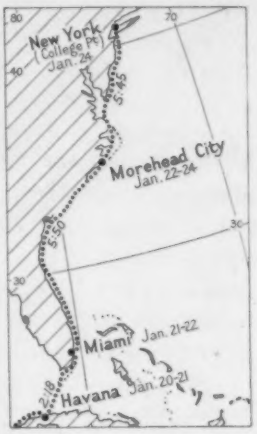

FIG. 38—Stages of the flight from Havana home. Scale 1 : 40,000,000.

THROUGH MEXICO

As continuance of the flight to North America by way of Kamchatka and the Aleutians could not be considered in winter, the plane was transshipped to Vancouver, B. C., where it was again put in flying condition. Since the pontoons were retained, it was necessary to fly far south into Mexico before crossing to the Atlantic seaboard. This was no hardship, for western Mexico boasts one of the most beautiful coast lines in the world and one, moreover, that is not frequently seen from the air. With parts of the route I was already familiar from three previous journeys.

Leaving San Diego on January 14, we flew southward into Lower California, turning east midway down the arid peninsula to make a stop in the lovely harbor of Guaymas, Sonora. Between Guaymas and Mazatlán the shore is flat and sandy, a complete contrast with the magnificent cordillera that rises a short distance inland. Mazatlán, the chief port of the region, is a focus for the mining parties exploiting the rich Sierra Madre Occidental.

The whole distance from Mazatlán to Acapulco we looked down upon white, hard beaches that terminate the narrow riviera, guarded by unostentatious mountains draped in soft green foliage. Acapulco has the best harbor on the west coast of Mexico. Its excellence was recognized in the early colonial days, when it formed the port of entry for the Manila galleons on the eastern Pacific. The deep semicircular bay is almost landlocked, easy of access, and has so secure an anchorage that vessels can safely lie alongside the rocks that fringe the shore. We landed close by the town, and, while one could tell from the pitch of the surrounding hills that the harbor must be deep, we were hardly

prepared to discover that a hundred feet of line would fail to touch bottom.

Except for occasional rocky promontories, the coast from Acapulco to Salina Cruz consists of a flat foreshore, a half mile to two miles wide, thickly covered with low jungle backed by mountains rising to several thousand feet. All was green around here, in striking contrast to the barren sands of Lower California and the Sonora desert. Salina Cruz is the Pacific terminus of the Tehuantepec railroad and boasts an artificial harbor constructed at great expense when the line was completed in 1907. Two long, curving breakwaters were thrown out to enclose a large area into which a double line of quays was built. Six great warehouses, a large number of railroad tracks, and electric cranes were included in the project, and even one of the largest dry docks in the world. The photograph, Figure 32, shows the present condition of this ambitious project. Whether from diversion of traffic to the Panama Canal or from inability to prevent the heavy silting process in the mouth of the harbor, the port has been virtually abandoned.

At Salina Cruz we turned north to cross the isthmus. Happily the weather was clear, with none of the violent winds for which Tehuantepec has long been notorious. We reached Carmen without incident, but on the next flight luck deserted us. Delays in leaving Carmen and increasingly adverse winds off eastern Yucatan postponed our attempt to cross the straits until late afternoon. When Cuba failed to appear at sundown, I became uneasy and turned back toward the mainland, where a landing in darkness was made behind a reef. We were unable to leave the plane and spent an exciting night on board as it pitched and rolled in a 7-force gale.

The final stage of the cruise began with a flight from Havana to Miami, thence along the Atlantic coast with a single stop at Morehead City, N. C. On January 24 *Asulinak* returned shiveringly to home waters, with the cabin temperature now 114 degrees lower than it had been over the Persian Gulf! I think we must have drawn long breaths as New York harbor slipped upward towards the tired pontoons, for the thrilling moment of homecoming was at hand. The world was no longer a mysterious painting on a library globe. It had developed into an amazing series of impressions, to which an extra dimension had been added: the privileged view of its surface from aloft.

INSOLATION, TOPOGRAPHY, AND SETTLEMENT IN THE ALPS*

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WHEN on a mountain summit one seldom tires of watching the movement of sunlight and shadow over the landscape. Even if the day is cloudless there is constant fascination in the dwindling and shifting of the shadow patterns as the morning advances; in their widening and merging into new forms as the sun sinks (Fig. 2). These changing forms give the geographer food for thought; for he knows well the value of solar radiation to dwellers in mountain regions.[1] He knows that crops that ripen early on slopes exposed to the sun may fail to ripen at all on the opposite side of a valley. He knows that in the Alps north-facing mountain slopes are generally left to forest but that pastures extend high on south-facing slopes. These facts he recognizes in general terms. The shifting play of shadows, moving as they do in accordance with rigid mathematical laws, may suggest to him the possibility of precise investigation of the interrelationships of insolation, topography, and human life in mountain regions.

The present study is a development of this thought. In regions of high altitude and where Alpine land forms predominate, insolation is especially important as a geographical factor, partly because the solar radiation received at the earth's surface increases with altitude and partly because the boldness of the topography causes sharp local contrasts in the duration and intensity of insolation.

Methods of map analysis are suggested in the following paragraphs as a means of discovering and isolating the effects of topography on insolation. Three types of map have been selected to show correlations of geographical significance for the particular regions under discussion. The maps show (1) the winter noonday shadow area, (2) time periods of sunshine at the equinoxes, and (3) the noonday intensity of insolation at the equinoxes, all as determined by topography. How these maps were constructed will first be explained; then the maps themselves will be interpreted in the light of what they reveal; and finally some further refinements of the method will be suggested.

The time-period and intensity maps, it must be observed, show potential, not actual, amounts of sunshine. Given clear weather from sunrise to sunset, the frequencies indicated would be experienced

*The writer is indebted to Dr. C. A. Stewart of the Department of Mathematics, University of Sheffield, for criticism regarding the use of various mathematical formulae suggested in this paper.

[1] See Roderick Peattie: Height Limits of Mountain Economies: A Preliminary Survey of Contributing Factors, *Geogr. Rev.*, Vol. 21, 1931, pp. 415–428.

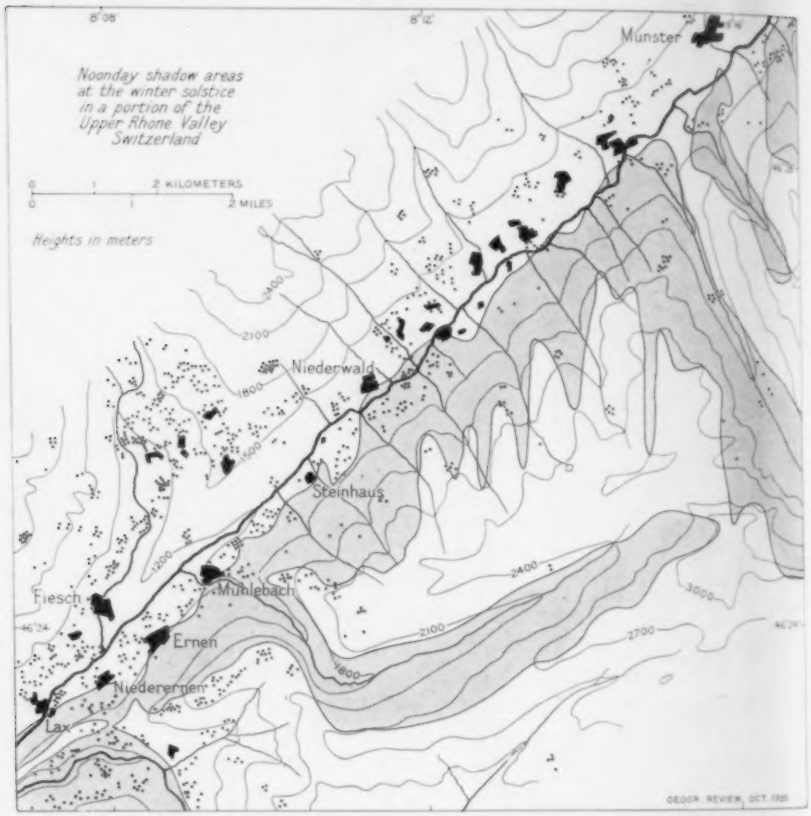

FIG. 1—Settlements in relation to the noonday shadow areas at the winter solstice in a portion of the upper Rhone Valley, Canton of Valais, Switzerland. Scale: 1 : 120,000.

as a result of topographic interference. Local records of mean atmospheric conditions for the time of year would be needed for any more precise calculations, but unfortunately actual data concerning sun intensity and periodicity are notoriously infrequent in the reports of weather stations in general.

THE DECEMBER-SOLSTICE SHADOW

Figures 1 and 4 show for certain valleys in the Alps the areas covered by the longest noonday shadow of the year.

Shadow maps of this kind are made as follows. Profiles are plotted for each of a series of closely spaced parallel lines (i.e. at distances of never more than five millimeters for a map of the scale of 1 : 50,000). Each profile must be oriented parallel to the horizontal direction of the sun's rays—hence at midday from south to north—and must be drawn without exaggeration of the vertical scale. The angle of the sun's altitude is determined for the day, hour, and latitude. Parallel lines intersecting the base of each profile at this angle may then be drawn in such a way as to show the limits of areas in shadow, and the positions of these limits may then be transferred to the map and joined to delimit the entire shadow area.

Time Periods of Insolation

Though significant, the midwinter shadow area is by no means the only important factor of insolation, especially in relation to agriculture. Topography may make a region sunless at noon, but it does not necessarily follow that it is without sun at every hour of the day. The play of sunlight between peaks and shoulders of the ridges may delay "sunrise" until afternoon or bring "sunset" into the morning hours. Maps may be constructed to show the duration or time periods of insolation for a day. The accompanying maps (Figs. 2, 3, 5, and 6) have been drawn for the equinoxes, since the solar-radiation income, in mountainous regions particularly, is at a maximum during the spring,[2] and therefore the topographic effects on its duration are more significant. Any influence that may hasten or retard the melting of snow and the rise of soil temperatures at this time of year is of the utmost geographical importance in Alpine regions.

For the time-period map the areas of shadow are calculated for every hour of sunlight and plotted on separate tracing sheets (Fig. 2). The shadows are determined, as before, from a series of parallel profiles. These, however, must be oriented differently for each map, since the profiles must trend parallel to the hour angle of the sun for each hour. Furthermore, the altitude of the sun must be known for each hour.

The changes in the sun's altitude may be determined with a high degree of accuracy by the method indicated in the Appendix on pages 615–617. By superimposing the maps for each hour a single layered shadow map may be obtained, on which gradations of tints or shadings indicate areas of high, intermediate, and low time periods of insolation. Figure 5 is an example of such a map.

The Noonday Intensity of Insolation

Figure 3 shows with some precision to what degree the changing detail of topography affects the intensity of insolation over a portion of the area represented on Figure 2. The settlements here are compensated for low time period of insolation by a position in the highest noonday-intensity area of the entire district. They lie within a zone where the intensity at noon exceeds 80 per cent (and locally 90 per cent) of the maximum available insolation.

Figure 3 is constructed from the following calculations. Whatever the maximum absolute sun value may be at any hour of the day as a result of latitude and sun altitude, only a certain percentage of the available intensity is received on a unit area, according as a ray falls more nearly vertically or glances horizontally along the surface. The intensity experienced at any point results from the horizontal hour angle of the sun, the horizontal bearing of the valley, the degree of slope on the valley side, and the angle of the sun's altitude. If at a given point α is the angle between a vertical and the sun's ray, β is the angle of slope, and Γ is the horizontal angle between the line of the sun's ray and a perpendicular to the valley direction, then the intensity value (I.V.) at that point is equal to $\cos \alpha \cos \beta \pm \sin \alpha \sin \beta \cos \Gamma$.[3]

[2] Anders Ångström: On Radiation and Climate, *Geografiska Annaler*, Vol. 7, 1925, pp. 122–142.

[3] Plus sign when the aspect is toward the sun's ray; minus sign when the aspect is away from the sun's ray.

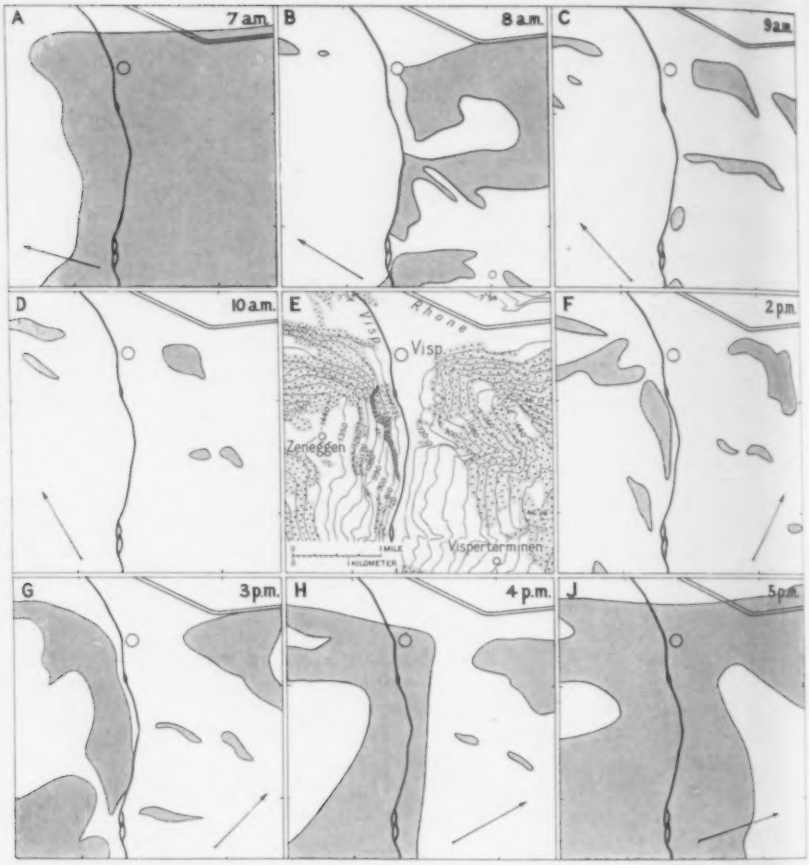

FIG. 2—Shadow and insolation areas hour by hour at the equinoxes in vicinity of Visp, Canton of Valais, Switzerland. Scale: 1 : 140,000. Only traces of shadow exist at 11 a. m., noon, and 1 p. m. Direction of the sun rays indicated by arrows. Topography shown on E derived from 1 : 50,000 Siegfried map of Switzerland, reproduced with the permission of the Swiss Topographical Survey.

To construct the map of intensity values the original contour map is covered with a fine grid of squares each measuring not more than 4 millimeters by 4 millimeters (or less, as the clarity of the map symbolism permits). In relation to a selected station within each square, angles α, β, and T are calculated and the formula applied. The results (as plotted, for example, on the left-hand half of Figure 3) give a close net of equidistant insolation values expressing for each station the percentage of the maximum available intensity at that time that can be received (i.e. the percentage of the insolation that would be received on a unit area where a ray meets the surface at right angles in both planes, horizontal and vertical). Isointensity lines are then interpolated for selected intervals to complete the map.

THE RHONE VALLEY IN SWITZERLAND

In the lower part of the portion of the Rhone Valley (Valais, Switzerland) shown on Figure 1 the river is cutting a gorge in the old glacial floor. This gorge between Niederernen and Niederwald

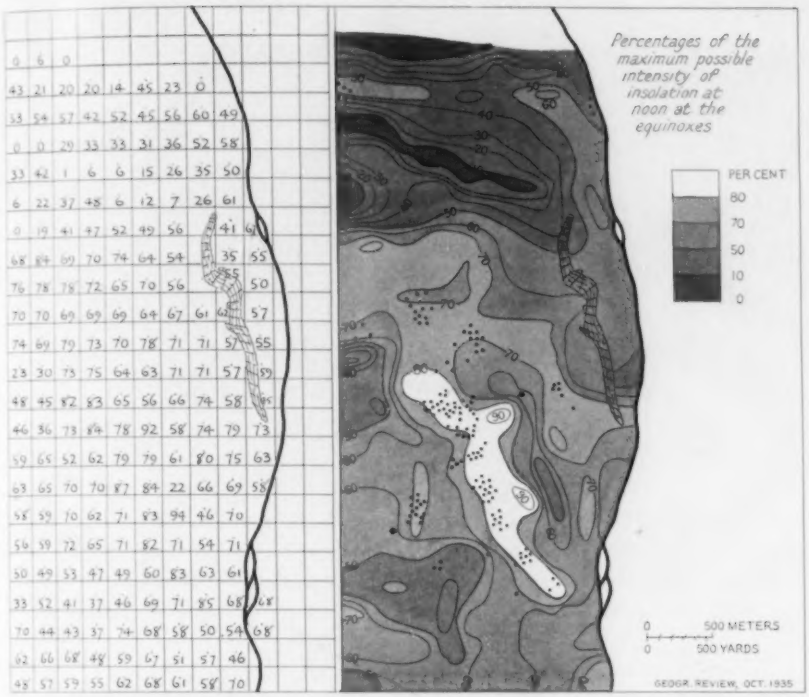

FIG. 3—Percentages of the maximum possible intensity of insolation at noon at the equinoxes in the area west of the Visp shown on Fig. 2. To left: percentage calculations by squares; to right: intensity of insolation in relation to settlement (isointensity lines drawn for 10 per cent intervals). Scale: 1 : 66,000.

happens to be well over toward the *adret*, or sunny side of the valley. As a result settlements near the valley floor are largely confined to the terrace on the *ubac*, or shady side. Figure 1 confirms observations made in other regions at altitudes of more than 1100 meters (ca. 3400 feet) that permanent villages and hamlets at these heights are seldom found within the midwinter noonday shadow area and that those on the *ubac* tend to stand along the edge of this shadow line (see also Fig. 4).

The two commune centers of Zeneggen and Visperterminen (Fig. 2E) lie at considerable altitudes but are thereby placed in favorable time-period areas (as revealed on a time-period map comparable to Figure 5 but not reproduced here). Zeneggen, in fact, occupies the highest time-period zone within the territory covered by Figure 2 outside the Rhone Valley trough to the north. The Visp Valley is unfavorable to settlement both in topography and in insolation. The south slopes of the Rhone Valley are comparatively steep and sunless; hence they are left to forest except over the fragmentary glacial bench in the northwest. Many textbooks point out the significance of the gentle gradients of such glacial benches in terms of

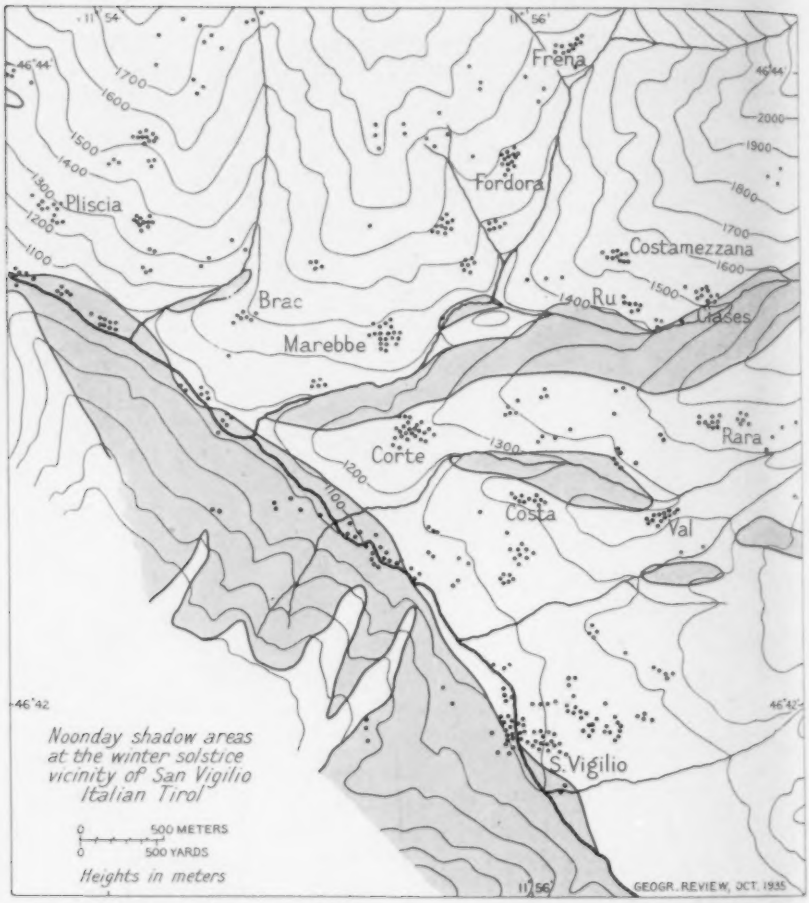

FIG. 4—Noonday shadow areas at the winter solstice in a portion of the Val di Marebbe, Italian Tirol. Scale: 1 : 44,000.

Alpine human geography, but the insolation maps show in detail how one of them has been partly cleared and utilized for pasture because of the additional advantages in the high time period and high intensities of insolation that it receives—factors not immediately obvious from study of topographic maps alone.

THE VAL DI MAREBBE, ITALIAN TIROL

The Val di Marebbe, a tributary of the Valle di Badia (Gaderthal), Italian Tirol, is chosen to illustrate the value of all three types of map in the geographical study of one region. This valley cuts transversely across changing outcrops and gives roughly comparable rock and soil conditions on both *adret* and *ubac*. The settlement pattern consists of small nucleated hamlets of permanent occupation scattered over

the area from the valley bottom up to heights of 1540 meters. Though changing rapidly, the region is still in many respects undeveloped, and as yet tourist and other "imported" industries have only slightly modified natural local adjustments to environment. The main factor determining the extent of settlement vertically has been the degree to which areas can be profitably cleared for agriculture. The limit under most favorable circumstances is reached at about 1600 meters (ca. 5300 feet), and even wheat is cultivated at altitudes of more than 1500 meters. Observations and inquiries in the field have shown that, except for some settlements and industries on the valley bottom, the outstanding factor determining land utilization is the amount and intensity of insolation received. Whereas the *ubac* is little dissected, is largely forested, and is occupied by only an occasional farm, the *adret* is more widely dissected into roughly east-west valleys, which give local topographic changes interesting in their effect on insolation and, through this, on the distribution of population.

In the light of these facts Figures 4 to 6 suggest some correlations of value. From Figure 4 it will be seen that settlements avoid or stand on the edge of the noonday shadow area, except for some habitations near the valley bottom. As most of these are mills used in the summer season, they are near the river and hence just within the shadow zone —a fact, however, that does not materially affect them. Apart from the mills, there are only occasional farm buildings on the lower *ubac* slope within the shadow zone.

San Vigilio is by far the most important settlement today and is rapidly growing. Increasing accessibility of the valley through the opening of first-class roads through most of the region has contributed to its importance as a tourist and administrative center. The small and rather isolated hamlet of Marebbe, however, gives its name to both commune and valley. In view of this fact it is striking to find from Figures 5 and 6 that Marebbe is in the most favorable part of the whole commune as regards insolation. From Figure 5 it will be seen that whereas San Vigilio lies partly within a comparatively low time-period area—even though the site is the best on the valley bottom in this respect—Marebbe, on the other hand, lies on the edge of the region of highest time period. Actually this is the largest area of so long a time period in the whole commune (excluding areas above 1600 meters). The position of San Vigilio is of interest in that its growth has been influenced by the counterplay of two opposing physiographic controls. To the southwest the less favorable insolation frequency (particularly in relation to the winter shadow area) should favor growth eastward into a higher time-period zone. Here, however, an immense boulder fan that is still the path for active landslide and avalanche debris, moving from east to west, sets a limit to eastward village growth.

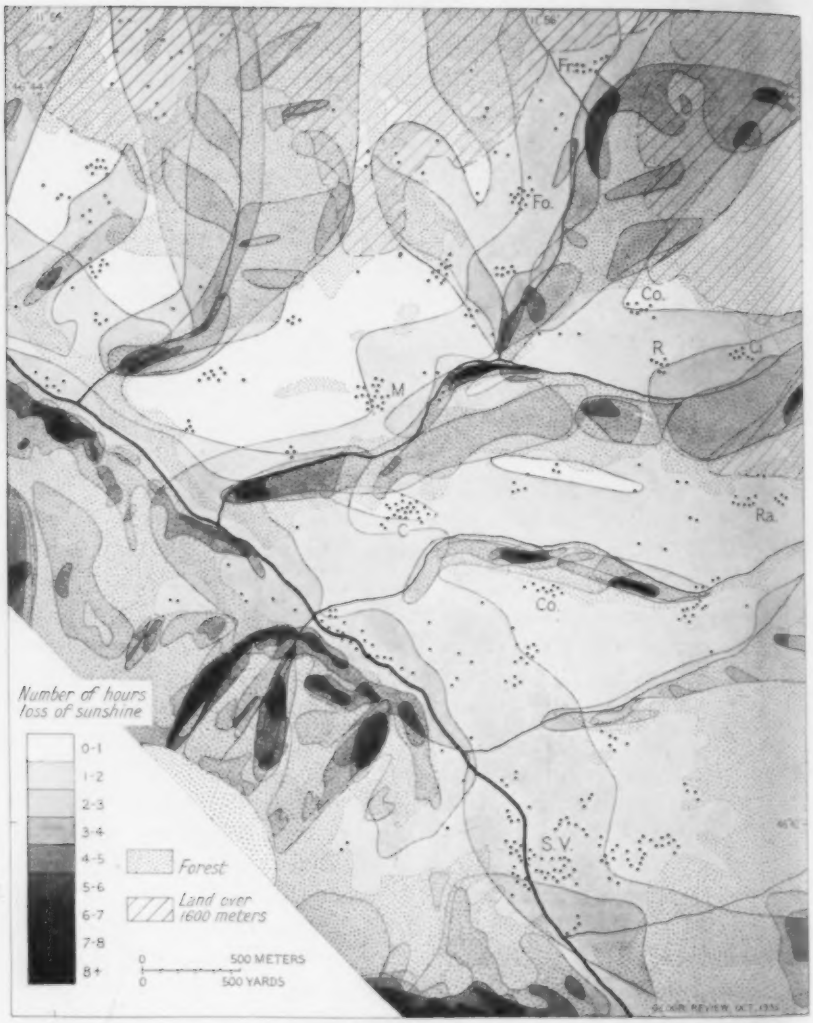

FIG. 5—Time periods of insolation at the equinoxes in the Val di Marebbe. Scale: 1 : 37,500.

Again, by comparing the two centers on Figure 6 it will be seen that not only does Marebbe border an area of far higher intensity than that of any area near San Vigilio but this area is the largest in the commune with values exceeding 90 per cent at an altitude of less than 1600 meters. Therefore Marebbe stands on the edge of the only large area within the commune that receives not only a high time period but also a very high noonday intensity of insolation. Corte, south of Marebbe, takes advantage of a comparatively flat Alpine bench and lies precisely on that small portion of it where the time period of insolation is longest. A study of the site of this hamlet in relation to the factors of insolation depicted on Figures 5 and 6

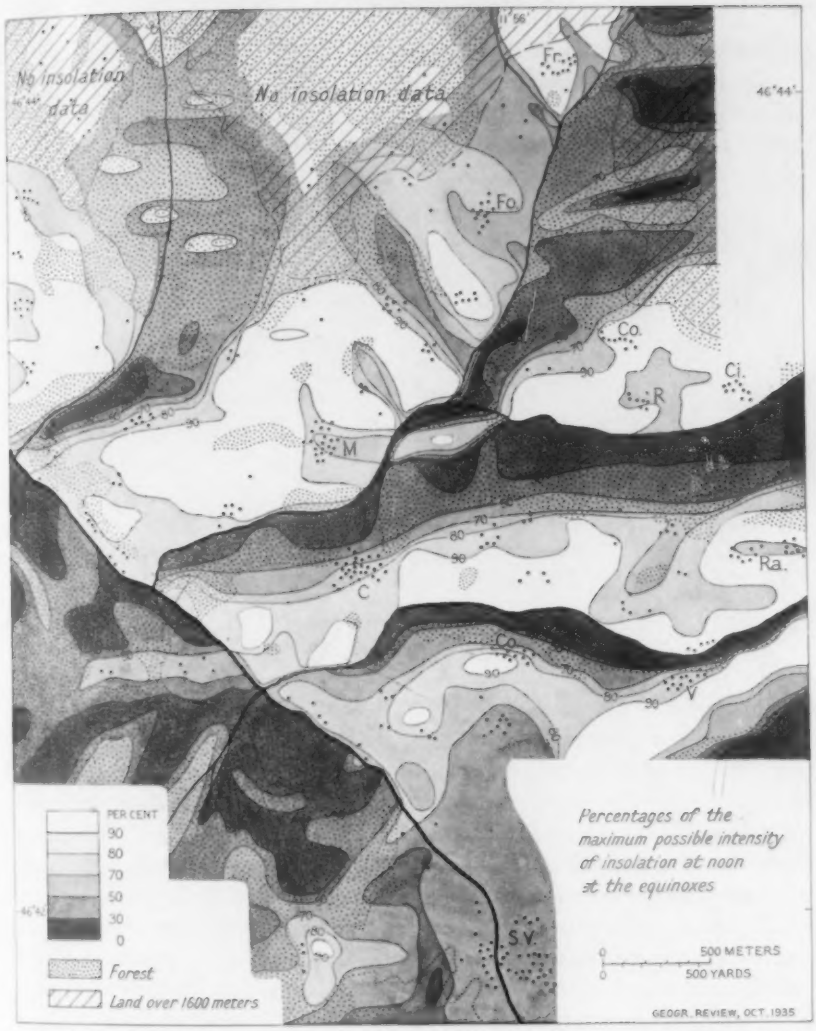

FIG. 6—Percentages of the maximum possible intensity of insolation at noon at the equinoxes in the Val di Marebbe. Scale: 1 : 34,000.

reveals certain tendencies that have been found to characterize other regions for which maps of these types have been constructed. Above a height of about 1300 meters settlements seem to show a preference for high time period rather than high intensity of insolation in the choice of site. Therefore they generally stand not only outside the winter shadow line but also either within or flanking high time-period areas for spring. Where, however, a settlement cannot occupy a position experiencing a high time period of insolation in spring (although placed outside the winter midday shadow area), almost invariably it seeks compensation by the selection of a site within a

high intensity area. Thus Corte—in a high time-period area—occupies a position of only moderate noonday intensity, whereas Ciases (north of Rara) and Frena and Costa (above Marebbe) have selected positions of the highest intensity (90 per cent +) to compensate for the lower time period. All four are, of course, outside the winter noonday shadow area.

FIG. 7

FIG. 8

FIG. 7—The highest wheat field in the part of the Val di Marebbe studied (above Rara, at an altitude of about 1600 meters).

FIG. 8—Upper limits of settlement and cultivable slopes within the 90 per cent intensity area near Rara.

LAND UTILIZATION AND INSOLATION IN THE VAL DI MAREBBE

When correlated with field studies it is possible to trace from Figures 5 and 6 the degree to which both time period and intensity of insolation at higher altitudes become of rapidly increasing importance as factors influencing land utilization. With but few exceptions—and these below 1400 meters—land with an insolation value of less than 50 per cent is left to forest. The only land cleared for agriculture and pasture on the *ubac* is within the two areas where the intensity value rises to at least 50 per cent. A high farmstead above San Vigilio and the only arable land within the adjacent area cleared of forest lie where the intensity value rises to at least 80 to 90 per cent, even though it is necessary to climb to a height of 1400 meters to reach this. Inquiries in the field revealed that the sun power is not great enough to ripen wheat on the *ubac*, where, too, the yield of rye is at least 30 per cent less a hectare than it is on the *adret*. The map shows the intensity values associated with these conditions.

On the *adret* conditions are better. Crops ripen at far greater altitudes: ripening wheat has been gathered by the writer at heights of 1600 meters above Rara and Costamezzana (Fig. 7), in both places where there is a loss of not more than one hour of sunlight and the intensity value exceeds 90 per cent. It is grown freely above Marebbe and in other places locally above 1400 meters, always where the intensity value exceeds 90 per cent.

Insolation appears to exert a very close control, since in the valley northeast of Marebbe (from Costa to Frena) wheat is not grown, as it is at the same altitudes above Marebbe. The maps show that the side of the valley near Costa and Frena loses two hours of possible sunshine and that, in addition, over large areas the intensity values fall to 70–80 per cent or even less. It is apparently this double loss

FIG. 9

FIG. 10

FIG. 9—Frena, at the upper limits of permanent settlement (the intensity values of the slope in the foreground are over 90 per cent).

FIG. 10—From Costa looking toward the slopes below Costamezzana, showing the relation of intensity values to land utilization.

of both time period and intensity that rules out wheat as a safe crop, though rye has been found ripening at 1650 meters within the intensity area of 90 per cent above Frena.

In general terms, therefore, the following controls seem to obtain for land over about 1350 meters and below about 1650 meters in this region: (1) Land receiving less than 50 per cent I.V. is left to forest. (2) Land receiving 50–70 per cent I.V. makes meadow but not arable land. (3) Land receiving more than 70 per cent I.V. is used for most cereals, roots, etc. (4) Wheat is grown only on slopes receiving not only a high time period but also an I.V. of at least 90 per cent. (5) Above about 1650 meters insolation values have no effect and land is again left to forest, or finally to alp pasture.

It would seem that on this basis practically all suitable land has been developed. There are, however, a few exceptions. Portions of the valley opposite Frena are left to forest, though they receive an intensity value higher than 50 per cent; but this occurs only where altitudes exceed 1350 meters and where in any case the time periods are low. Conditions are different in the small valley above Brac. Though time periods and intensities are inadequate in the lower part of the valley, the upper part below 1600 meters is suitable in both respects for at least meadow, where now the land is still left to forest. There are other very small areas where the land is left to forest even within an intensity area of 90 per cent and at comparatively low

altitudes. There is one such area, for example, on the south-facing slope north of Brac; but here the small portion of forested slope not only is steep but receives a time period two hours shorter than that of adjacent surfaces.

Finally, it is of interest to compare the spring insolation maps with information collected from various parts of the valley regarding rates of snow melting at this season. The conditions portrayed on the maps should be associated with a snow cover that lasts from November to early March on the *adret* slopes but persists until early, and even late, April on the *ubac*—latest of all in the main valley opposite Marebbe, where the intensity value falls in many places to less than 20 per cent, even to 10 per cent. A depth of snow of one meter is common throughout March over most parts of the *ubac*. Again, on the *ubac* in the main valley no month is completely free from frosts, whereas on the *adret* slopes are normally frost-free from May until early September.

Further Refinements of the Method

The time-period maps show how many hours different areas are in sunlight. They make no distinction between the weak sunlight of early morning or late afternoon and the strong sunlight of midday. Furthermore, on these maps sunlight that falls obliquely along slopes is given the same value as sunlight that strikes slopes vertically. The noonday-intensity maps, on the other hand, take account of the pitch and direction of slopes but are constructed for the noon hour only and in terms of percentages of the maximum available intensity. If further refinement in the method is desired, maps may be constructed to express values of insolation in terms of energy (gram calories).

In determining sun values for each hour the following formula is used: $E.V.$ (i.e. energy value expressed in terms of gram calories per square centimeter per minute) $= C a^{l} d$. Here d refers to the formula $\cos \alpha \cos \beta \pm \sin \alpha \sin \beta \cos \Gamma$ as used before for calculations of the noonday-insolation percentages. C is the solar constant[4] (1.93 gram calories per square centimeter per minute); a is the fraction of C that passes through the atmosphere when the sun's rays fall vertically (this obviously increases with increasing altitude above sea level); l is the thickness of the atmosphere along the path of the sun's rays, assuming that a vertical ray passes through unit thickness. Clearly the value of a must be assessed with due regard for altitude; it may be obtained from a graph on which radiation at sea level is assumed to average 0.50, and at 6000 feet 0.75, of the radiation received at the outer limits of the atmosphere.[5] The value of l may be obtained from the following table[6] or from a graph that would show also thicknesses for intermediate altitudes:

[4] The solar constant is defined as "the amount of energy [that would be] received by a given unit area at right angles to the sun's rays, provided there were no absorption in the atmosphere, or provided the atmosphere were not present" (W. I. Milham: Meteorology. New York, 1912, p. 39).

[5] Julius Hann: Handbook of Climatology, Part 1, General Climatology, transl. by R. DeC. Ward. New York and London, 1903, p. 104.

[6] Milham, *loc. cit.*, and Hann, *op. cit.*, p. 103.

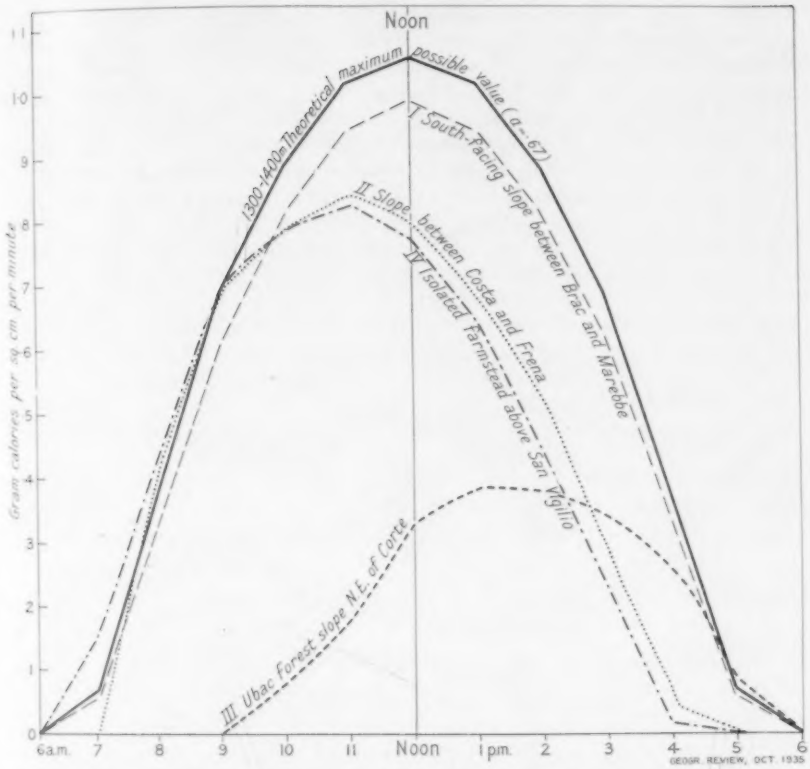
Noon
1300-1400m Theoretical maximum possible value (a = .67)
I South-facing slope between Brac and Marebbe
II Slope between Costa and Frena
IV Isolated Farmstead above San Vigilio
III Ubac Forest slope N.E. of Corte
Gram-calories per sq. cm per minute
6a.m. 7 8 9 10 11 Noon 1pm. 2 3 4 5 6
GEOGR. REVIEW, OCT. 1935

FIG. 11—Five curves showing the extent to which details of topography affect the amount and the symmetry of distribution (with respect to noon) of the total insolation for one day at the equinox for the four stations analyzed in Table I, and for a maximum index value calculated for an altitude of 1300–1400 meters.

SUN'S ALTITUDE . . .	0°	5°	10°	20°	30°	40°	50°	60°	70°	80°	90°
THICKNESS OF ATMOSPHERE . . .	44.7	10.2	5.56	2.9	1.99	1.56	1.31	1.15	1.06	1.02	1.0

With the aid of this formula a total-energy map for the day may be constructed as follows:

(1) The topographic map is covered with a fine grid of squares, as explained above (p. 604). (2) Shadow areas are delimited for each time interval, as on the time-period maps. (3) Within the areas where there is no interception of sunlight on each shadow map the energy value is calculated for every square by applying the formula $E.V. = C a^{l} d$. (4) The sum of the values obtained at each shadow interval within each square gives a total value for the day that can be recorded on the map. This value, however, is an index, rather than an actual, value, since it is the sum of values each of which refers to a value of one minute of time at each hour, not to the complete time period of 60 minutes for each hour.

A closer approach to an actual rather than an index value may be obtained by plotting on squared paper a graph of the hourly values for each station separately. From the calculated area of the graph the total gram-calory value for the day may be assessed. Such graphs, furthermore, are of interest in recording the degree to which topography alone affects the amount and the symmetry of the insolation for the day (see Figure 11).

Even this total cannot be regarded as the absolute gram-calory value received at the surface, since the calculations have been based on the formula $C a^l d$, which, although of great use for obtaining general estimates for different latitudes or seasons of the year, cannot be relied on for very exact and precise calculations. In many respects for geographical correlation a more suitable value is that recording the percentage of the maximum possible insolation value for the day (i.e. that received under most favorable conditions) that is actually received each day at each station, as a result of topography. For this the following additional calculations should be made.

(5) A surface that faces due south and whose degree of slope is the complement of the sun's noonday altitude will receive 100 per cent noonday intensity and varying percentages at all other hours of the day. If the energy value $C a^l d$ is calculated for this hypothetical slope for every time interval—assuming that the slope is at no time cut off from the sun's rays—the sum of these values gives a theoretical index value (or the area of the graph of these figures, a more precise total value), recording the highest possible theoretical insolation for the day. Results similarly obtained for definite stations on the map may now be expressed as percentages of this maximum value, and lines delimiting equal percentages may be plotted on the map. (Separate assessments of the theoretical maximum values will be required for different altitudes —i.e. with respect to the changing values of a.)

Results tabulated below for the four selected stations, for which graphs are given

TABLE I—INSOLATION IN TERMS OF ENERGY RECEIVED AT SELECTED STATIONS AT THE EQUINOX

	I		II		III		IV	
LOCALITY	Between Brac and Marebbe		Below Fordora (Between Frena and Costa)		Forested slope on *ubac* N.E. of Corte		Isolated farmstead above S. Vigilio	
ALTITUDE	1300–1400 meters		1400–1500 meters		1300–1400 meters		1400–1500 meters	
TIME PERIOD	6–6		7–5		9–6		6–5	
HOUR	d (= % I.V.)	$Ca^l d$ (gr. cal. cm² per minute)	d (= % I.V.)	$Ca^l d$ (gr. cal. cm² per minute)	d (= % I.V.)	$Ca^l d$ (gr. cal. cm² per minute)	d (= % I.V.)	$Ca^l d$ (gr. cal. cm² per minute)
7 a. m.	27	.056	..	....	..	....	56	.151
8 a. m.	51	.325	65	.412	..	....	67	.431
9 a. m.	70	.610	72	.688	..	....	73	.698
10 a. m.	84	.805	76	.782	9	.078	75	.780
11 a. m.	91	.940	75	.838	17	.175	74	.820
noon	98	.982	70	.795	32	.329	68	.765
1 p. m.	91	.943	61	.680	37	.382	58	.645
2 p. m.	84	.810	47	.486	39	.376	43	.445
3 p. m.	71	.618	29	.273	39	.337	24	.228
4 p. m.	52	.333	7	.043	40	.256	2	.014
5 p. m.	28	.058	..	....	39	.081	..	....
(A) TOTAL VALUES FOR ACTUAL STATIONS	Total gr. cal. value	Sum of hr. index values	Total gr. cal. value	Sum of hr. index values	Total gr. cal. value	Sum of hr. index values	Total gr. cal. value	Sum of hr. index values
	387.84	6.48	297.3	4.997	116.76	2.014	295.32	4.977
(B) MAXIMUM THEORETICAL VALUES	421.8 (a = .67)	7.06	459.1 (a = .7)	7.68	421.8 (a = .67)	7.06	459.12 (a = .7)	7.68
A as % of B	From graph total values	From sum of hour indices	From graph total values	From sum of hour indices	From graph total values	From sum of hour indices	From graph total values	From sum of hour indices
	92%	92%	64.7%	65%	27.7%	28%	64.1%	64.8%
	1	2	3	4	5	6	7	8

Below double lines, columns 1, 3, 5, and 7 refer to calculations based on the complete measurement of the graph of hourly values. Columns 2, 4, 6, and 8 refer to calculations based on the sum of hourly indices only.

in Figure 11, show that the energy percentages for the whole day—whether taking hourly-index or total-energy figures—are only about 5 per cent less than the noonday percentages alone, whether we consider *ubac* or *adret*, slopes facing east or slopes facing west. In view of this fact the construction of the complete total-energy map has not seemed necessary for the region under consideration, especially considering the somewhat laborious calculations involved.

A map depicting percentages of either the total actual or the total index values received on different surfaces might, however, show marked and important differences from the noonday percentage map; for example, in the Marebbe district in winter, when sun altitudes are lower generally, or in regions of different topography, where noonday rays in spring are more widely intercepted. For this reason the method is put forward for consideration.

Possible Applications of the Methods

The application of the foregoing methods of map analysis and construction has been considered with the problems of Alpine geography particularly in mind; i.e. where local time periods and intensities of insolation in the spring have a special significance. The methods may, however, be applied to regions of any latitude[7] or be considered in relation to valleys of any degree of slope and orientation; the pertinent calculations, moreover, may be made for any hour or time of the year that may be selected as being more especially critical.

The existing adjustments of Alpine settlement to critical factors of insolation have been brought about more or less unconsciously as a result of centuries of trial and error. The process has been accompanied, no doubt, by much wasted effort as men have striven to exploit slopes receiving too little sun. It is conceivable that methods of map analysis similar to those outlined could be applied in planning for the future exploitation of mountain regions. In determining the best uses to which land may be put in such regions insolation should perhaps receive as much attention as questions of soil, topography, climate, and many of the other matters on which students of land utilization are today laying stress.

Appendix—Methods of Finding Hourly Changes in Sun Altitudes and Time and Bearing of Sunset or Sunrise[8]

1. The altitudes may be obtained graphically as follows (Fig. 12, to left):

The latitude, e.g. 46° 30′ N., and the sun's declination, e.g. 0°, being known, we have:

(Colat.)	$s =$	43.5° $Z\,P$
(Polar Dist.)	$z =$	90.0
	$s + z =$	133.5 $Z\,B$
	$s - z =$	46.5 $Z\,E$

Along a vertical line representing the meridian set off $Z\,P$, $Z\,B$, $Z\,E$ to a stereographic

[7] See also Friedrich Lauscher: Beziehungen zwischen der Sonnenscheindauer und Sonnenstrahlungssummen für alle Zonen der Erde, *Meteorol. Zeitschr.*, Vol. 51, 1934, pp. 437–449.—Edit. Note.

[8] These methods have been devised by Mr. A. J. Potter of the Royal Geographical Society, London, to whom the writer is indebted for the Appendix.

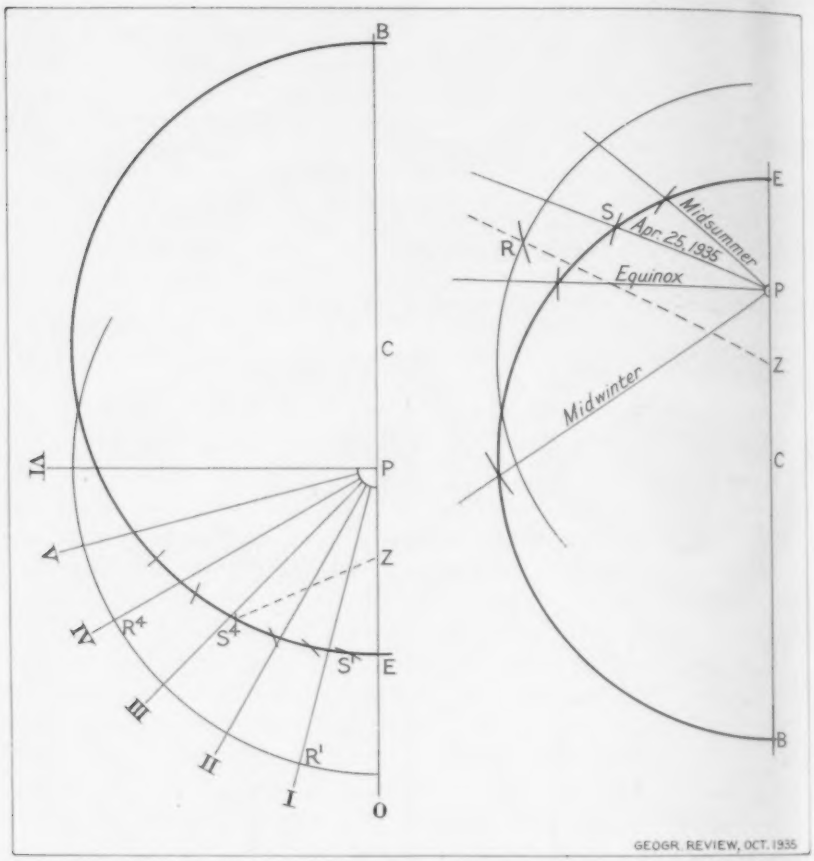

FIG. 12—Diagrams illustrating (at left) method of finding hourly changes in sun altitude and (at right) time and bearing of sunrise or sunset.

scale,[9] with E away from or towards B according as $Z\ E$ is negative or positive.

From P draw radial lines at intervals of 15° to represent the hour divisions (only p. m. in diagram).

With center C, midway between E and B, strike a sufficient arc of the circle that would pass through these points, and with the same radius, but now with center P, strike an auxiliary arc, cutting the radial lines at the point(s) R; and with center(s) R and radius = $P\ C$ cut the main arc at the point(s) S, on that side of $P\ R$ away from C.

Then $Z\ S$, measured with the scale, is the zenith distance, e.g. 69.9° at 4 p. m., whence the altitude is 20.1°.

The point(s) S need not be joined to Z unless the azimuth or true bearing is also required, in which case this can be read off as the angle $P\ Z\ S$; e.g. 247.3°.

The following results are thus obtained:

[9] That is with lengths regulated by the tangent of half the angular value. A suitable scale can be obtained from Messrs. C. F. Casella & Co., Fitzroy Square, London, W.1, at a cost of 3s. 6d. and postage. With the scale is supplied an explanatory leaflet covering other applications of the principle, based on a paper by A. J. Potter, "The Stereographic Solution of the Spherical Triangle," *Empire Survey Rev.*, Vol. 2, 1933–1934, pp. 226–238 (see also pp. 345–346 and Vol. 3, 1935, pp. 152–157).

	Zen. Dist.	Alt.
0 =	$Z\,E$	43.5
I	48.3	41.7
II	53.4	36.6
III	60.9	29.1
IV	69.9	20.1
V	79.7	10.3

2. To find time (and bearing) of sunset or sunrise (correspondingly) at, say, Sheffield (Fig 12, to right):

(Colat.)	s =	36.5°	$[P\,Z]$
(Zen. Dist.)[10]	p =	90.8	
	$s + p$ =	127.3	$P\,B$
	$s - p$ =	−54.3	$P\,E$

Along a vertical line representing the meridian set off $[P\,Z]$, $P\,B$, $P\,E$ to scale, with E away from or towards B according as $Z\,E$ is − or +.

With center C, midway between E and B, strike main arc, representing horizon [and with same radius, but now with center Z, the auxiliary arc].

With center P and radii = polar distances, i.e. 90° ± declination, cut main arc at point(s) S. Join $S\,P$. Then angle $Z\,P\,S$ is local apparent time,[11] e.g. 56° = 3^h44^m at midwinter.

Z need not be plotted and construction in square brackets should be omitted if bearing is not required.[12] If it is required, complete as follows: [With center S and radius = $Z\,C$, cut auxiliary arc at R, on side of $P\,S$ toward C. Join $Z\,R$. Then $P\,Z\,R$ is the true bearing or azimuth.]

[10] The addition of 0.8° is to allow for semidiameter and for refraction.

[11] For local mean time add or subtract equation of time, according to directions in an almanac.

[12] The construction thus simplified is the basic principle of an indicator (designed by Mr. Potter) that gives the result for any latitude at a glance.

THE RELATION BETWEEN FIELD PATTERNS AND JOINTING IN THE ARAN ISLANDS*

Lester E. Klimm
University of Pennsylvania

THE Aran Islands, off the west coast of County Galway, Ireland, have attracted considerable attention in recent years by reason of the picturesqueness of the customs, costumes, and speech of their inhabitants and the drama of men against barren land and wild sea that has been playing there for centuries.[1] They are of further interest, however, to those who seek to find reasons for the way man does things. Here the people have made a highly developed adjustment to a stern and unusual environment.

The islands stretch across the mouth of Galway Bay, forming a barrier running roughly northwest-southeast. They are of Carboniferous (probably Upper Carboniferous) limestone, the beds of which are nearly horizontal. The ground rises in a series of more or less regular terraces from the northeast coast to a central ridge. From this the surface slopes gently southward and westward, either to low sea cliffs, as on the south coasts of Inishmaan and Inisheer, or to high cliffs on the corresponding coast of Inishmore.

The apparent barrenness of these islands first impresses the visitor. Gray rock everywhere predominates. It forms the surface of large areas; it juts through the soil of the pastures; and it appears in the maze of fences with which the land divisions are marked off. But this land is richer than it appears at first glance. In the fissures of the many-jointed limestone soil has collected and plants grow. Because of the inherent richness of the soil derived from the limestone the plants make excellent fodder, and much of the area supports cattle, sheep, and goats of a quality better than the average. The fences have been constructed not only to enclose small patches of garden or pasture but also to clear the land of stones.

Field and Fence Patterns on Inishmore

On Inishmore, the largest island, and perhaps on Inishmaan and Inisheer to a lesser extent, these fences form over considerable areas a pattern that is apparently a definite adjustment to a peculiarity in the geologic structure of the island.

On looking out over the surface of Inishmore from an eminence such as the abandoned lighthouse above Oghil or the walls of Oghil

*The field work for this study was done in 1933–1934 under a fellowship from the Social Science Research Council.

[1] See L. E. Klimm: Inishmore: An Outpost Island, *Geogr. Rev.*, Vol. 17, 1927, pp. 387–396.—Edit. Note.

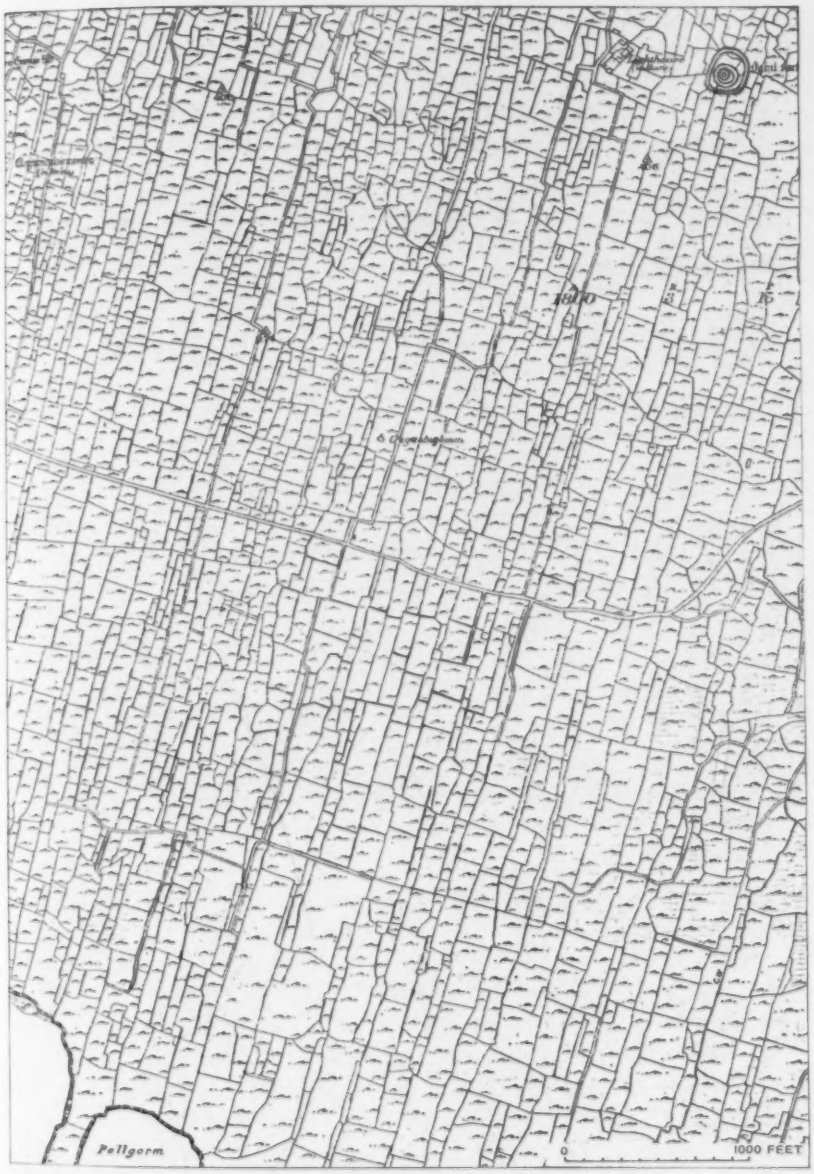

FIG. 1—Field pattern south of villages of Cowrugh and Oghil, Inishmore, showing fence lines trending N10°E in conformity with trend of jointing. Scale 1 : 12,300. (Reproduced with the permission of the Minister for Finance of Saorstát Eireann from Sheet 110, County Galway, of the six-inch Ordnance Survey map, Ireland.)

Fort, near by, one is not struck at first glance by any regularity of design. The walls and the predominantly bare surface are perhaps too nearly of the same color to make the pattern striking. But study Sheets 110, 111, and 119 (County Galway) of the six-inch Ordnance

Survey map of Ireland and the pattern begins to appear. Confined largely to the area south of the main road running from west to east along the axis of the island, it occupies the high ground that slopes gradually from the central ridge to the sea cliffs of the south coast. It is most noticeable due south of the village of Oghil, south of Onaght

FIG. 2—The relation between the strike of the joint and the fence line is apparent. Typical of thousands of fields.

village, and on the southeast end of the island. The area occupied by this pattern covers about half of the island's surface.

It will be found that the fences bounding the long sides of each field trend a few degrees east of north. This trend may be seen best on Figure 1, which shows the fence pattern just south of Oghil village, where the pattern is represented in perhaps its most highly developed form. Here most of the fields are several times as long as they are wide, and the long walls have a uniform orientation about N10°E.

How did this uniform pattern come about? A few minutes' study in the field shows that the fences are built along the lines of the main system of joints in the limestone. These joints and their attendant fissures, common to Carboniferous limestone,[2] are a marked feature of the generally level surface in the particular area under discussion. Figure 2, which shows plainly the relationship of fence to joint, could be duplicated in thousands of fields.

[2] For some other examples see F. J. North: Limestones, Their Origins, Distribution, and Uses, London, 1930, pp. 314, 315, 454, and 455.

In the higher parts of the islands the presence of soil depends on the breaking of the rock along the joints. The rate at which soil accumulates is largely a resultant of the hardness of the rock, the frequency of jointing, and the depth of the joints. An area of relatively "new" jointing is shown in Figure 3. The limestone is for the most part

FIG. 3—An area of relatively "new" jointing. The width of the widest ridge between the fissures in the foreground is about 18 inches.

hard and brittle; it does not disintegrate rapidly but breaks easily where joints are numerous. Belts of remarkably close jointing, many about 100 feet in width and extending for a mile or more along the direction of the joints, develop into shallow depressions in which the breakup of the rock is more rapid. Into these depressions the surface runoff flows and increases the rate of soil accumulation.

The tendency to weakness along lines of close jointing is one of the important controls of topography in the islands.

> The transverse valleys, including Gregory and Foul Sounds, bear nearly N. and S., and in Inishmore and Inishere there are ravines, having a similar bearing; most of them run along breaks or fissures in the strata. . . .
>
> The submerged valleys, that is Gregory's and the Foul Sounds, may be along lines of break; however, as they are obscured by water, it is only safe to record that they have a similar bearing to the principal lines of break and fissures, and to the main system of joints (about N.10-E).[3]

[3] G. H. Kinahan, Hugh Leonard, and R. J. Cruise: Explanatory Memoir to Accompany Sheets 104 and 113 with the Adjoining Portions of Sheets 103 and 122 (Kilkieran and Aran Sheets), of the Geological Survey of Ireland, Illustrating a Portion of the County of Galway, *Ireland Geol. Survey Memoirs*, Dublin, 1871, p. 26.

The long, narrow belts of thin soil in a generally soilless region were probably first fenced to serve as pastures or meadows. A month of field work showed definitely that the width of the fields varies with the frequency of the jointing, the more frequent jointing resulting in longer and narrower fields of better pasture and the less frequent jointing in wider fields of poor pasture or bare "crag." The largest areas uninterrupted by fences are found in places where the strata

FIG. 4

FIG. 5

FIG. 4—An unjointed "crag" of limestone. Fence lines and fields are not controlled by jointing in such areas.

FIG. 5—A *boreen*, or lane. The relation to a strike of the jointing is apparent.

are practically unbroken; for example, in the large "fields" south of Ourtnagapple village (Fig. 4) and south of Killeany village.

It may be seen from Figure 1 that the boreens, or narrow lanes giving access to these fields, also run along the strike of the joints. The one in Figure 5 was photographed within the area of the sketch map (Fig. 1) and shows the relation plainly. The ridge left between two joints, moreover, makes a good foundation for a fence, and the early builders were probably led, consciously or unconsciously, to follow the most obvious lines and build their fences along the joints in an area where no other marked physical features are present.

It is also probable that the land system was not unfavorable to the development of such a field pattern. The islands have been occupied from very early times by a cattle-raising people. One of the first concerns of such a people would be to clear the better pasture areas of loose stones and to pile the stones into fences to keep the cattle from roaming. It is likely that the narrower fields were fenced first because they were the richest. The distribution of the land worked by each family seems to have changed but little from the earliest times through the succession of the landlords and down to the present day of peasant proprietorship. The holding, or *cannagora*, as described by Barry in 1885, "could feed a cow with its calf, a horse, some sheep for their wool, and give sufficient potatoes to support a family."[4] Most of the

[4] J. G. Barry: Arran of the Saints, *Journ. Royal Hist. and Archeol. Soc. of Ireland*, Ser. 4, Vol. 7, 1885–1886, p. 489.

cultivated land and meadow is on the lower ground where underlying shales prevent too rapid underdrainage and encourage the accumulation of more soil; the pasture lies back on the higher ground to the south. It is to be doubted whether there ever was much commonage in Aran. It was necessary to fence to clear the land, and cattle and

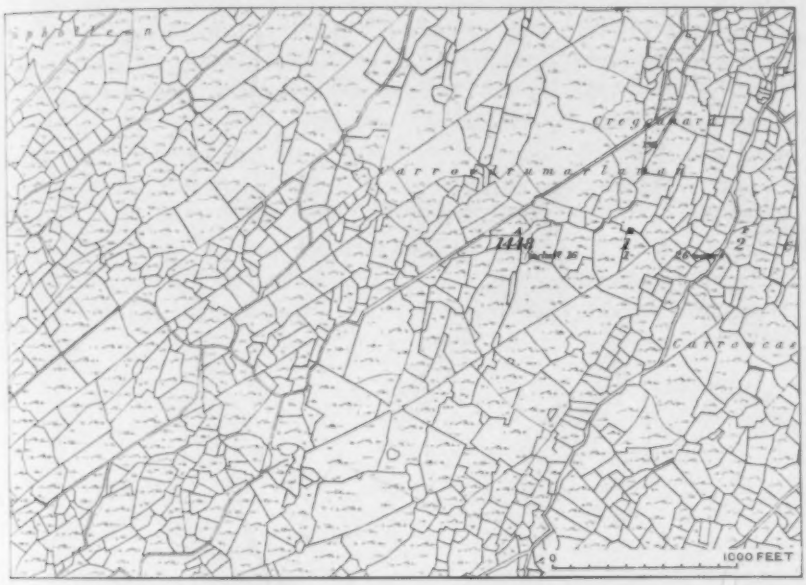

FIG. 6—Field pattern southwest of village of Largy, Inisheer. The fences and lanes trend E25°N. Scale 1 : 12,300. (Reproduced with the permission of the Minister for Finance of Saorstát Eireann from Sheet 120, County Galway, of the six-inch Ordnance Survey map, Ireland.)

sheep could not be allowed to roam at will because of the danger of their falling down cliffs or breaking their legs in fissures.

INISHMAAN AND INISHEER

The regularity of the field pattern characteristic of Inishmore is not found throughout the Aran Islands. In the northern part of Inishmaan "the joints have no regular bearing," though "in the south part they coincide with those on Inishmore, being about N.10°E."[5] Only in a relatively narrow strip near the southeast coast, however, is there a field pattern that would seem to have any close connection with the N10°E strike of the joints, and this is not very plain. The breakdown of the joint-field relationship may be due to the fact that the low cliffs representing the drop from one series of strata to another are much the most marked features of the topography and thus go far toward controlling the field pattern.

[5] Kinahan, Leonard, and Cruise, *op. cit.*, p. 35.

In an area about one half mile due south of Kinbally village on Inishmaan the orientation of the fences and boreens is more or less uniformly E25°N, and the regularity of this pattern stands out in fairly marked contrast with the irregularity of the pattern around it. A similar regular pattern is evident in the southwestern part of Inisheer (Fig. 6), where some of the fences continue more or less uninterruptedly for a mile or more along this approximate E25°N line. These patterns may be a partial response to a set of subsidiary joints reported by the Geological Survey[6] as having this strike on Inisheer but not mentioned as existing on Inishmaan.

It might be of interest to investigate the whole subject of field pattern in the Arans and its relation to other features, physical and otherwise. It would undoubtedly be found that common controls of field pattern such as shore line, cliff faces, roads, house distribution, etc. are of importance here as elsewhere. In this study, however, attention has been confined to a type of relationship found in very few other regions.

[6] *Ibid.*, p. 36.

THE MOUNTAIN SYSTEMS OF NORTHEASTERN ASIA*

S. V. Obruchev and K. A. Salishchev

[With separate map, Pl. V, facing p. 640]

BEFORE 1926 northeastern Siberia, within the limits surveyed in the present paper, was little known either geographically or geologically. The coastal margins, where a number of expeditions had worked, were somewhat better known than the interior. These expeditions had succeeded in visiting the shores of the Polar Sea between the Yana River and Bering Strait, the Chukchee peninsula, and the Sea of Okhotsk. However, the materials obtained for even these districts proved fragmentary and failed to provide a clear orographic picture.

Explorations in the Interior

Of the interior only the Anadyr basin had been explored in any detail—by the expedition of 1912 under the direction of Polevoi.[1] Farther south the routes of Sarychev in the eighteenth century and of Maidel and Chersky in the second half of the nineteenth century had led obliquely across the region. Maidel, from material gathered during his expeditions of 1868–1870 and based on investigations of the northern part of the region[2] and on scanty data obtained by questioning the natives, worked out an orographic scheme that has been retained up to the present both in descriptions and on maps. Although this scheme represented a great step forward when first suggested, its roughness was even then very clear.

With the economic development of the U.S.S.R. it became more and more evident that further study of northeastern Siberia was much needed. Without a just notion of its structure and more or less accurate maps no thorough practical knowledge of this vast land could be gained.

In order to investigate the geography and the geological structure of northeastern Asia the authors undertook four expeditions during the period 1926–1933.[3] The first of these, in 1926, was equipped by the Geological Committee for the study of the upper course of the Indigirka River and the southern part of the Verkhoyansk Mountains; the second, in 1929–1930, by the Academy of Sciences of the U. S. S. R.,

*The text of this paper is by Professor Obruchev, the maps by Professor Salishchev.

[1] P. Polevoi: Anadyrski krai (The Anadyr Region), *Trans. Geol. Committee*, N.S., 1915, p. 140.

[2] Maidel went from Yakutsk via Verkhoyansk, Sredne-Kolymsk, and the Bolshoi Anyui River to the upper part of the Anadyr River and along the south slope of the Anadyr Mountains.

[3] The geological and morphological observations during these expeditions were made by Professor Obruchev, the cartographical work and determination of the astronomical points from 1926 to 1930 by Professor Salishchev.

for the investigation of the Kolyma basin; the third and fourth, in 1932–1933, by the Arctic Institute, for the examination of the coast of Bering Sea and Chukchee Land. The first two expeditions were made in the usual way—by reindeer, horse, and boat; the expeditions in 1932–1933 were made by airplane, which allowed a quick reconnaissance of a considerable region. During the airplane expeditions

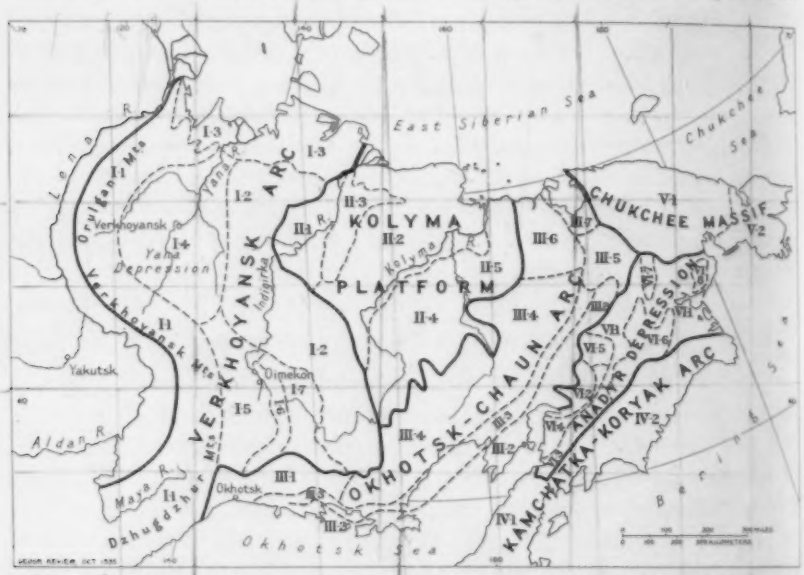

FIG. 1—Northeastern Asia: key map showing principal physiographic divisions. (I) *Verkhoyansk arc:* 1, Verkhoyansk Mountains, etc.; 2, Cherski Mountains, etc.; 3, coastal plain; 4, Yana depression; 5, Oimekon plateau; 6, Tas-Kystabyt Mountains; 7, Nera plateau. (II) *Kolyma platform:* 1, Indigirka lowland; 2, Kolyma lowland; 3, Alazeya plateau; 4, Yukagir plateau; 5, low mountains structurally related to Kolyma platform. (III) *Okhotsk-Chaun arc:* 1, Okhotsk slope of the major divide; 2, eastern and southern border ranges; 3, depression; 4, Gydan Mountains; 5, Anadyr plateau; 6, Anyui Mountains, etc.; 7, Chaun depression. (IV) *Kamchatka-Koryak arc:* 1, Kamchatka peninsula; 2, Koryak Mountains. (V) *Chukchee massif:* 1, Western Anadyr Mountains; 2, Eastern Anadyr Mountains. (VI) *Anadyr depression:* 1, Anadyr plain; 2, Penzhina plain; 3, Parapolski Dol; 4, Penzhina Mountains; 5, Nalgim and Russki mountains; 6, Rarytkin Mountains, etc.; 7, Pekulnei Mountains; 8, Zolotoi and Ushkani mountains. Scale of map 1 : 27,000,000. (On Plate V for Volymsk read Kolymsk.)

of 1932–1933 Salishchev used a new method of visual route surveying, which made possible, without any great difficulties, the compilation of a map on the scale of 1 : 1,000,000.[4]

Simultaneously a number of other institutions sent out expeditions, whose objects were: geological researches in selected districts; a hydrographical survey of the Yana, Indigirka, and Kolyma river systems; an investigation of the routes in the interfluves; and a complex botanical, zoölogical, and economic study of the Anadyr basin and the Koryak district. These investigations, which were limited to certain areas, have furnished data supplementary to the materials

[4] K. A. Salishchev: Vizualnaya semka s samoleta i ee znachenie dlya sostavleniya 1/1,000,000 karty (Visual Survey from an Airplane and Its Significance in the Plotting of a 1 : 1,000,000 Map), *Arctica*, Vol. 1, 1933, pp. 139–143.

gathered by the present writers as a basis for the orographic scheme outlined in this paper.[5]

The Proposed Orographic Scheme

The scheme that we are now able to propose differs considerably from the one that has hitherto been generally accepted. If, on the new map, only the distribution of elevations is considered, a wide mountain belt may be distinguished, bordering the region on the west and joining in the south with another, somewhat narrower belt that trends northeastward to the Chukchee peninsula. North of this mountain system is a lowland, and east of it, almost entirely separated from it by the depression of the Anadyr and Penzhina rivers, extends the narrow mountain system of Kamchatka and the Koryak Mountains. However, a closer study shows that the area may be divided into the following orotectonic regions:

1. The Verkhoyansk arc, which borders the region on the west and includes the parallel Verkhoyansk and Cherski mountain ranges as well as the lower Oimekon and Nera plateaus, the Tas-Kystabyt Mountains lying between them, and the Yana depression.

2. The Kolyma platform, which occupies the area north of the Verkhoyansk and Okhotsk-Chaun arcs. It includes the Alazeya and Yukagir plateaus and the Kolyma and Indigirka lowlands.

3. The Okhotsk-Chaun arc, which extends along the coast of the Sea of Okhotsk and thence northward to Chaun Bay on the Arctic coast. Its major subdivisions are the Gydan Mountains and the Anadyr plateau.

4. The Kamchatka-Koryak arc, which occupies the Kamchatka peninsula and the shore of Bering Sea north to latitude 63° and is composed of the Kamchatka and Koryak mountains. Kamchatka does not come within the scope of this paper.

5. The Chukchee massif, which occupies the extreme northeast corner of Asia, between Chaun Bay and Bering Strait.

6. The Anadyr depression, which is between the Okhotsk-Chaun and Kamchatka-Koryak arcs and the Chukchee massif. It comprises a series of small mountain groups and three large lower areas.

The Verkhoyansk Arc*

The Verkhoyansk arc is bounded on the west and east by prominent mountain chains. The ranges on the west, of which the Verkhoyansk

[5] A detailed description of separate parts of the land will be found in a series of papers by the authors. See also S. V. Obruchev: Materialy dlya tektoniki severo-vostochnoi Azii (Material on the Tectonics of Northeastern Asia), *Problems of Soviet Geology*, 1934, Vol. 2, pp. 182–200, and Vol. 3, pp. 1–16.

*The major features of this arc are shown schematically on Figure 1. Inasmuch as we did not have enough new and exact cartographical material for the northern and western regions, only the eastern part of this arc is represented on the larger-scale detailed map (Pl. V).

Mountains are the most important member, extend northward toward the Arctic Sea in the form of an S parallel to the Aldan and Lena rivers. The west slope of the Verkhoyansk Mountains, which descends to these rivers, is steep and shows alpine forms along its entire extent. Recently glaciated valleys cut far into it. The east slope is a vast highland, whose broad, flat valleys and smooth mountain forms descend gently to the lower central region; its glaciation has been of the icecap type. In some places—for instance, in the southern part—a series of chains runs parallel to the main axis. The Cherski Mountains, on the east border of the Verkhoyansk arc, were discovered by our expedition in 1926.[6] They run in general parallel to the Verkhoyansk Mountains and consist of low, dissected plateaus and a series of parallel chains, in many places deeply dissected and divided into separate groups. Northwest of the Kolyma River, where this mountainous region becomes a pronounced unit, it broadens, and the individual chains reach their greatest heights. The northern extension of the range, the Tas-Khayakhtakh Mountains, is as yet but little explored.

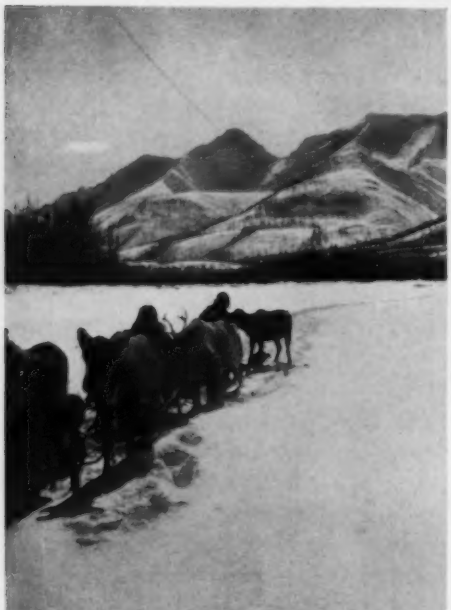

FIG. 2—Valley of the Khandyga River in the Verkhoyansk Mountains; a glaciated valley with terraces.

Between the mountainous borders of the arc is a broad and considerably lower zone, which may be divided conveniently into three regions of relatively low land and one major range. The northern depression, drained by the Yana River and its tributaries, may be likened to a broad, flat-bottomed cup whose sides rise gradually to the surrounding ranges. The central part of the depression near Verkhoyansk is one of the coldest regions of the world. To the south are the Oimekon plateau and its southeast branch, the Nera plateau, which are separated by the Tas-Kystabyt Mountains, a series of irregular alpine groups trending parallel to the southern parts of the Verkhoyansk and Cherski mountains. Our expedition and

[6] The Cherski Mountains were named by the State Geographical Society of the U. S. S. R. in honor of the late geologist Chersky, who died in the Kolyma district in 1892, at the beginning of his three-year expedition.

observations of the meteorological station established there in 1929 have shown that the Oimekon plateau is colder than Verkhoyansk and evidently represents the cold pole of the world.[7] The Nera plateau ranges topographically from an extremely flat surface to a deeply dissected region at the headwaters of the Kolyma River.

The southern parts of the Oimekon and Nera plateaus and of the Tas-Kystabyt and Cherski mountains were formerly shown on maps as united with the southern parts of the divide between the Pacific Ocean and the Polar Sea to form one large range, the Stanovoi or Kolyma Mountains. This is incorrect, since individual parts of this divide represent morphologically, as well as geologically, different formations. They are connected only at the Okhotsk slope, by a large arcuate tectonic disruption, in which the Okhotsk-Chaun arc arose. This will be discussed more fully under the section devoted to the Okhotsk-Chaun arc.

Geological Structure

The geological structure of the Verkhoyansk arc is in entire conformity with its relief. It is a mighty folded zone. The less elevated central part consists of Triassic rocks; the border zones show pre-Cambrian and Paleozoic formations. The south, Aldan River, slope of the Verkhoyansk Mountains is pre-Cambrian; in the middle and northern parts of the range the Paleozoic is exposed in the axial region, though not along the main axis. The Paleozoic appears in the easternmost chains of the Cherski range and along the axis of the Tas-Khayakhtakh Mountains. The chief heights of the Cherski and Tas-Kystabyt mountains are connected by numerous granite batholiths. The main axis of the Verkhoyansk Mountains is composed in the south of Triassic sandstones and farther north of Permian rocks. The arc is bounded by zones of tectonic fractures. The uplift of individual parts has been unequal, the horsts of the Cherski and Tas-Kystabyt mountains rising more rapidly than the rest of the area.

The Verkhoyansk and Cherski Mountains

The Verkhoyansk Mountains reach their greatest height in the southern part, where the mountain junction Suantar-Khayata, or Urakancha, was formerly shown. The mean altitude of the range there is about 2000 meters, some summits reaching 2500 meters. The Cherski Mountains have suffered especially strong dissection in their south extremity. Here the range widens to 250 kilometers and is divided into chains and groups separated by broad valleys and small mountains 1000 to 1300 meters in height, though individual groups often rise to 1800-2000 meters. The lower massifs are almost like tablelands, but the higher ranges have alpine forms. In the southeast the chains of the Cherski Mountains are prolonged as separate groups beyond the Kolyma River, where they are 1500 to 2000 meters in height, dominating the plateau of the Sea of Okhotsk divide. On the slope descending to the Sea of Okhotsk the Cherski Mountains are no longer pronounced; here another morphological region begins. North of the Kolyma River the range narrows to 150 kilometers and becomes more marked. Here two independent chains run parallel to the main range, on the east; in the northern of these, the Ilin-Tas, alpine forms are abundant and glaciation has been recent. We learned by questioning the natives that there are

[7] See note in the record section of the present number of the *Review*.

still small glaciers near the Inyali and Chybagalakh rivers. In the Ilin-Tas Paleozoic formations occur. The main massif of the Cherski Mountains reaches its greatest height in the headwaters region of the Indigirka River, where the mean elevations are 2000–2500 meters and individual groups reach 3000 meters (Mt. Chen on the Inyali River, 3114 meters). The chains run parallel to one another in a west-northwest direction; they are sharply defined and are separated by deep, narrow alpine

FIG. 3—The Verkhoyansk Mountains as seen from the bordering ranges, with the Tompo River in the foreground.

valleys. Farther to the west, beyond the Indigirka, some of them give place to a little dissected, elevated plateau.

The northern chains of the Cherski Mountains are connected with the Tas-Khayakhtakh Mountains by the short Kekh-Tas range, in which small glaciers have been found. The Tas-Khayakhtakh, as yet but little known, are composed of high ridges about 80 kilometers wide, with steep, jagged peaks rising to 2000 meters and with passes at 1000–1500 meters.[8]

THE YANA DEPRESSION

The Yana depression is encircled by mountains except for a relatively narrow opening that connects it with the Arctic coastal plain. The slopes of the Verkhoyansk Mountains descend gently from the west and the south, and it is difficult to decide where the high upland of the range ends and the tableland forming the slopes of the depression begins. In the Verkhoyansk district the flat-topped elevations reach 550–600 meters; nearer the mountains, eastward and southward, the heights gradually increase to 800–900 meters. On the right bank of the Yana River, opposite Verkhoyansk, a high ridge connected with the granite massifs stands out sharply. The depression is drained by one river, the Yana, and its tributaries.

THE OIMEKON PLATEAU AND NEIGHBORING REGIONS

The Oimekon plateau, to the south, forms the divide between the Sea of Okhotsk and the Indigirka River. Its central part is occupied by the Oimekon depression

[8] V. Vakar: Geologicheskie nablyudeniya v polyarnoi chasti khrebta Cherskogo (A Geological Reconnaissance in the Polar Part of the Cherski Mountains), *Bulls. United Geol. and Prospecting Service of U.S.S.R.*, Vol. 51, No. 49, 1932; V. Fedortsev, oral communications, 1934.

(600-900 meters), which trends northwestward along the Indigirka River for about 25 kilometers. Farther southwest the plateau is higher, some summits reaching 1500 meters. To the north it probably merges imperceptibly into the Yana depression. The plateau, except for the depression, remains entirely unexplored.

The Nera plateau stands out sharply as a lower area of little relief between the Cherski and Tas-Kystabyt mountains. Its southern part forms a rather flat divide,

FIG. 4—Central range of the Cherski Mountains, west of the Indigirka River.

about 1200–1300 meters high, between the Kolyma River and the Sea of Okhotsk. Farther north, about the headwaters of the Kolyma River, it is deeply dissected, and individual summits rise 100 meters above the mean level of the plateau, 1000–1200 meters. Its north margin gradually descends to the valley of the Indigirka.

The Tas-Kystabyt Mountains, which include a series of irregular groups, with heights of 2000–2200 meters, decreasing to 1500–1700 meters in the south, descend abruptly to the plateaus on both sides.

On the north the Verkhoyansk Mountains, the Yana depression, and the Cherski Mountains border on a coastal plain—a dreary, monotonous, undulating tundra with innumerable lakes. At longitude 141° E., however, a series of low, isolated elevations marks the prolongation of the Cherski Mountains.

The Kolyma Platform

The Kolyma platform, in contrast with the mountain complex of the Verkhoyansk arc to its west, is conspicuous for the wide extent of low-lying swampy tundra. The drainage basins of the two chief rivers, the Kolyma and the Indigirka, show little or no relative relief, and the larger rivers and their tributaries flow northward in broad meander belts to the coastal tundra of the East Siberian Sea. A smaller, more elevated region, the Alazeya plateau,[9] lies between the

[9] On former maps there was shown, at the site of this plateau, north of latitude 66° N., the Tomus-Khaya range, which was thought to divide the basins of the Indigirka and the Kolyma and to be joined in the north to another arclike range, the Alazeya Mountains. The name "Tomus-Khaya" belongs, however, only to the south extremity of the Alazeya plateau, near Ozhogina. The plateau was distinguished as an independent unit by K. A. Salishchev in 1932.

FIG. 5

FIG. 6

FIG. 5—Kolyma lowland west of the Kolyma River.
FIG. 6—Chuvan Mountains.

major drainage systems and is almost completely surrounded by lowlands. Its generally flat surface is interrupted by rounded forms and a few more prominent individual summits and groups. Southeast of the Kolyma lowland the surface of the platform passes imperceptibly from Quaternary terraces of the Kolyma and Omolon rivers to a broad upland, the Yukagir plateau.[10] It continues to rise toward the south until it merges into the long, northward-spreading branches of the Okhotsk-Chaun mountain complex. The surface is gently undulating, with broad, flat-bottomed valleys; here and there small ridges and groups rise above it.

The Kolyma platform is a pre-Cambrian shield, which since the Proterozoic has been a stable area of resistant rocks, around which later folds have been formed. On the surface of the shield only gently undulating Mesozoic deposits and abundant effusive rocks and tuffs are found. The mountain groups, standing above the general level, are composed of granites and syenites. Unequal uplift combined with subaerial erosion led to the formation of the two lowlands of the shield.

[10] At the site of the Yukagir plateau there was shown on former maps a large chain, the Kolyma Mountains, uniting in the south with the Kolyma range. The new name was proposed in 1931 by the authors.

FIG. 7

FIG. 8

FIG. 7—Flood plain of the Anadyr River.
FIG. 8—Anadyr Mountains: one of the highest summits (2300 meters) with a small glacier.

In general the Alazeya plateau ranges from 200 to 400 meters in height. In a few places, especially in the northern part, individual summits and groups reach 700 meters.

The Indigirka lowland, the smaller of the two great depressions, is swampy and dotted with lakes. Here the tributaries of the Indigirka River have pronounced meander belts. Only between the Uyandina and Selennyakh rivers does the surface become slightly undulating, with ridges 10 to 15 meters high.[11]

The larger Kolyma lowland is likewise dotted with numerous lakes, especially in the northern part. Near the Kolyma River two terraces may be traced; the first rises 4 to 6 meters above the flood plain; the second, from 40 meters in the south to not more than 15 meters in the north. The lowland terminates in the south at the Verkhne-Kolymsk depression, which trends southward between the Cherski Mountains and the Yukagir plateau.

The Okhotsk-Chaun Arc

This region, the least known, is the most complicated structurally and the most difficult to resolve into separate elements. As a conse-

[11] Yu. D. Chirikhin: Predvaritelny otchet o rabotakh Indigirskogo Otryada Yakutskoi Ekspeditsii Akademii Nauk SSSR 1929–1930 gg. (Preliminary Report on the Work of the Indigirka Party of the Yakut Expedition of the Academy of Sciences of the U. S. S. R., 1929–1930), *Trudy Soveta po Izucheniyu Proizvoditelnykh Sil*, Akademiya Nauk SSSR, Yakut Ser., No. 6, 1932, pp. 1–46.

quence, its morphological divisions are somewhat doubtful; its delimitation from the mountain system of the Verkhoyansk arc is especially questionable.

As has been said, the Okhotsk-Chaun arc was united by a recent immense arclike disruption. The accompanying fractures intersected a great part of the more ancient Verkhoyansk arc, which near the

FIG. 9—Kongiin Mountains; limestone cliffs to left.

Okhotsk coast acquired forms connected with the newly imposed structures but farther inland retained the earlier forms. Therefore, in studying the land from the continental side one is inclined to place part of the Okhotsk coast among the morphological units of the Verkhoyansk arc, whereas investigations begun from the Okhotsk coast suggest that one should join the inland parts of the continental massif to the border arc.[12] If one joins, as we have done, the north slope of the uplands bordering the Sea of Okhotsk and the upper parts of the Kolyma and Indigirka basins to the Verkhoyansk arc, the south slope of these uplands must undoubtedly be referred to another orographic region. Such a division is somewhat artificial, but to attribute the north-south-trending elements of the Verkhoyansk arc to the east-west-trending part of the Okhotsk-Chaun arc would be still more artificial.

The Okhotsk-Chaun arc is bordered on the south in part by offshoots from the larger continental uplands and in part by a discontinuous coastal range structurally related to the new arc. In places this range extends into the sea as irregularly shaped peninsulas or reappears as small islands. Throughout most of its length it is separated from the larger continental mountains by a depression. The

[12] The former conception of the uninterrupted homogeneous Stanovoi range extending from Transbaikalia along the shores of the Sea of Okhotsk to the Chukchee peninsula is to be explained by the fact that these mountain systems were explored, and very superficially at that, from the sea side, the side of the arclike disruption. This explains also the difference of opinion concerning the south extremity expressed by explorers who approached it from the coast and from Yakutiya.

most prominent feature of the arc is a large range, the Gydan Mountains,[12] which runs northward nearly the entire distance from the region of the coastal range to the Chukchee massif. The dividing line between the Gydan Mountains and the south end of the Cherski Mountains can be drawn only tentatively, since the region has been but little explored. In places there is a distinct central axis along a

FIG. 10—A portion of the Anadyr plateau with the braided channels of the Emmuveem.

major ridge of the Gydan; elsewhere the mountains either spread out into complicated groups and crests, finely dissected and separated by glaciated valleys, or show a broad axis composed of a series of subparallel ridges with alpine forms. To the northwest of the main axis many long, high ridges extend into the lower country of the Kolyma platform. To the southeast along Penzhina Gulf, however, the mountains drop abruptly, the seaward rivers are deeply incised, and their valleys are glaciated. Farther north, where the main range runs parallel to the Anadyr lowland, its east slope is separated from the lowland along the greater part of its distance by a longitudinal depression and a lower mountain area, inland complements of the coastal depression and range. To the northeast of the Gydan Mountains the Anadyr plateau forms a connecting link with the Chukchee massif. Geologically the plateau is a graben between these two regions and is filled with recent effusives. It has a very smooth relief, above which low mountains rise in places. Two rather prominent mountain chains begin upon it and reach out to the west toward the Kolyma River. North of it is a lowland area extending to Chaun Bay on the border of the East Siberian Sea.

The geological structure of the Okhotsk-Chaun arc is little known; a more or less accurate picture can be drawn of only its central part,

[12] Until our expedition in 1929–1930 the range was named on maps the "Kolyma Mountains," according to Maidel's scheme. As early as 1856, however, Chikhachev called it "Gedan," and the inhabitants, the Evenki (Tungusses) and the Yakuts, still call it the "Gydan" (Coastal).

the region of the upper Omolon River. The arc consists, evidently, of sections of different origin—parts of an ancient shield and a folded zone—united by recent arclike disruptions.

The Okhotsk Coastal Region

From Okhotsk to Taui Bay, i.e. from the Verkhoyansk Mountains to the south end of the Cherski Mountains, the land is little known. It may be assumed that the elevated dividing plateau sends a series of spurs between the rivers out on the coastal plain. Only east of Okhotsk the Marekan Mountains, 600 to 1000 meters high, come fairly near to the sea. Farther east the steep slope of the mountain massif recedes from the sea, from which it is separated by a wide depression, the valley of the Taui River, and by the coastal range. The coastal range, or southeasternmost step of the arclike disruption, begins at the Lisyanski Peninsula and soon reaches a height of 1000 meters. Beyond the interruption formed by Taui Bay it reappears as Spafariev and Zavyalov islands and farther east as the Koni and Pyagin peninsulas. Here there are heights up to 1800 meters, and the central parts of the range show alpine forms. The depression separating this part of the foremost ridge from the continental massif is less sharply defined than on the Taui and reaches altitudes of 700 meters and more. Farther northeast the Taigonos peninsula forms the prolongation of the ridge. It has an average height of about 1000 meters and individual summits of 1500 meters and is separated from the Gydan Mountains to the west by a depression, the valleys of the Gizhiga and Paren rivers, whose divide is not more than 200 meters high.

The Gydan Mountains

The important Gydan Mountains may be regarded as beginning north of Taui Bay, where the steep slope of the continental massif borders directly on the sea. The entire mountain region from the Buyanda to the upper Korkodon River is as yet unexplored.

The Gydan Mountains in the district of the upper Omolon River constitute a wide mountain region with average heights of 1500–1600 meters, some crests reaching 1800–2000, and perhaps even 2200, meters. From the principal axis of the mountains long branches spread northward between the Balygychan, Sugoi, Korkodon, and Omolon rivers. The slope to the valley of the Penzhina River is little known. A series of spurs, the so-called Kamenny, Ushkani, and Ichigem mountains, reach out into the valley. The Kamenny Mountains are of moderate elevation, 600–700 meters, with summits up to 975 meters. The Ichigem range forms the beginning of that part of the Gydan that we investigated in our flights of 1933. We managed to see its entire east slope as well as the north end; part of the west slope could be seen from the Omolon River.

The north half of the Gydan has a high and fairly broad central axis composed of a series of ridges, 1800 to 2000 meters in height. On each side the mountain region slopes toward a foreland, though in some places longitudinal valleys sharply delimit the main axis with its steep slopes.

On the east slope of the northern Gydan is a longitudinal depression occupied by the headwaters of the Anadyr River and its tributary, the Eropol. This lowland is separated from the Anadyr depression by mountains, continued to the southwest in the distal ends of the Ichigem, Ushkani, and Kamenny mountains, in which the greatest heights, Stadukhina Mountain and others, evidently lie some distance east of the main axis of the Gydan. To the distinctly defined northern part of this higher range, divided by the transverse valleys of the Anadyr and Penzhina rivers, we have given the name of Chuvan Mountains. This chain is evidently a prolonga-

tion of the coastal range of the Okhotsk coast; the Anadyr-Eropol depression is in line with the depressions separating this ridge from the chief massif of the arc.

The main axis of the Gydan terminates abruptly in the northeast upon the Anadyr plateau, an area of smooth relief, interrupted in places by dissected mountains, table mountains, and chains of gently sloping hills. Its central part is an upland overflowed with andesites and liparites, on which is Elgytkhin Lake, 11 to 12 kilometers in diameter, in the crater of a Quaternary volcano. The plateau has a height of 900–1200 meters.

The Anyui Mountains

Two alpine mountain chains begin on the Anadyr plateau and run almost due west on each side of the Maly Anyui River. Until their local names can be ascertained we have temporarily called them the Southern and Northern Anyui chains.[14] West of the Angarka and Pogynden rivers they pass into lower mountain forms. The geological structure of the chains themselves is as yet unknown; possibly they continue the Chukchee-massif system. Between the Northern Anyui and the Chukchee massif, however, the Chaun depression, a lake plain of not less than 100 kilometers in diameter, extends far southward. If Chaun Bay is included in this depression, it reaches a length of 250 kilometers.

The Kamchatka-Koryak Arc

This arc consists of two parts, the Kamchatka peninsula and a large range, the Koryak Mountains,[15] which stretches along the coast of Bering Sea from Kamchatka to Cape Navarin. We are not concerned here with Kamchatka but shall consider only the north half of the arc. On maps, and especially on charts, this region was formerly called Koryak Land, though the ranges were shown as lying far from the coast and united directly with the Stanovoi Mountains.[16] In our investigations of 1932 we were able to ascertain that this mountain region extends to the coast of Bering Sea and that parallel ranges with a general northeast trend, separated by longitudinal valleys, may be defined. These ranges undoubtedly represent a single mountain system in direct prolongation of that of Kamchatka. At many points along the coast the mountains are alpine; in the central part the forms are somewhat softer, but the mountain groups are separated by deep glaciated valleys.

The Koryak Mountains are tectonically a typical folded zone formed along a Mesozoic-Tertiary geosyncline. The subsequent arclike thrust faults, which caused the formation of the border arcs of East Asia, coincide in general in their direction with the folding and mark the present boundaries of the range. Toward its west end the range widens to 250 kilometers; its chains spread somewhat like a fan, and between Cape Olyutorski and Goven peninsula a series of ridges deviates southward, interrupted by the shore line. Evidently only the northwest ridge extends to the Kamchatka peninsula, though even this ridge, as we ascertained on our flight of 1932,

[14] On some former maps, in the area occupied by the western part of the Northern Anyui appears the name "Labugenskie Mountains" and in the area west of the Pogynden River "Leledinskie Mountains." However, as far as we were able to ascertain, these names are entirely unknown to the natives.

[15] We named the Koryak Mountains after the region, since these mountains belong to the Koryak National District.

[16] Polevoi was the first to propose a correct scheme for this arc (*op. cit.*, p. 23).

is separated from the Kamchatka Mountains by a low divide 10 kilometers wide, across which the Parapolski Dol merges smoothly into the plain of the east coast.

The Chukchee Massif

The Chukchee peninsula and the area between the Anadyr basin and the coast of the Polar Sea are occupied by a mountain region, which in Maidel's scheme is named the Anadyr Mountains.[17] This region, which may be called the Chukchee massif, consists of two parts, somewhat different in form. The larger, lying to the west of a line between the Kresta Gulf and Kolyuchin Bay, is composed of a series of ranges trending in general to the northwest. The dominant range, which should retain the name Anadyr Mountains, is deeply dissected in its higher parts and is characterized by alpine forms and glaciated valleys. The eastern part of the Chukchee massif, i.e. the Chukchee peninsula, is of lower relief and is characterized by smooth, rounded forms and broad valleys trending northwestward independently of the contemporary direction of the rivers.

The massif lies within a region of Paleozoic folding. Since the Cimmerian orogenesis, which possibly affected the north border, it has reacted as a stable shield subjected to epeirogenic oscillations. Its contemporary limits are bounded by fracture zones.

The western division of the Chukchee massif reaches its greatest elevation in the Anadyr Mountains between Cape Severny and the Pekulnei Mountains. There, at the sources of the Amguema, Tanyurer, Osinovaya, and Kuvet rivers, peaks rise to 2000 and nearly 2300 meters. In the region of Kolyuchin Bay we expected to find Matachingai Mountain, 2799 meters high, dominating the country; but a thorough investigation of the entire region revealed only a series of summits not exceeding 1700–1750 meters. The appearance on maps of this exceptionally high mountain, which for a long time was a puzzle to geographers, is obviously to be explained by a mistake of the marine survey.

The eastern division of the Chukchee massif is a mountain region with average heights of 800–1000 meters and here and there in the central part summits of 1500 meters. A large depression runs from Mechigmen Bay to Kolyuchin Bay. These two bays, which are prolongations of the depression, are distinguished by shallow depths, whereas the other gulfs of the peninsula—Lavrentiya Bay, all the gulfs of the southeast corner, and the bays of the Kresta Gulf—show a distribution of depths typical of fiords. These fiords are believed to be connected with the most recent glaciation. In the Eskaten chain one small hanging glacier was found.

The Anadyr Depression*

This area of generally lower land lying directly south of the Chukchee massif separates the elevated country of the Okhotsk-Chaun arc from the Koryak Mountains. It may be conveniently subdivided

[17] The mountains themselves, inasmuch as they occupy the larger, northern part of the Chukchee National District and have almost no relation to Anadyr Land, should be named the "Chukchee Mountains." However, in order to avoid a frequent change of nomenclature, we shall retain the old name for the principal part of the mountains.

*The term "Anadyr depression" was proposed by Polevoi.

into three lowlands and a series of small mountain groups, some of which, although closely related structurally to the contiguous regions, have been placed for convenience within the Anadyr depression. By far the largest and most conspicuous of the lowlands is the Anadyr plain, a tundra dotted with small subcircular lakes of fluvial or marine origin. Toward the mountains it is undulating in many places and interrupted by hills of country rock. However, the striking features of this and the other lowlands are their comparative flatness and low mean elevation. The mountainous areas, generally speaking, may be separated into three predominant types: narrow, structurally controlled ranges, irregular mountain groups often connected by recent effusives, and basalt-capped summits. The higher mountain areas are deeply dissected and in places show pointed peaks and alpine crests; the lower are finely dissected and show numerous conical mountains or *sopkas*, table mountains, or smoothly rounded forms.

The Anadyr depression is an area of subsidence between the uplifted arcs to the northwest and southeast and the Chukchee massif to the north. It has been repeatedly overflowed with effusives. The more mobile parts, virgating branches of the Koryak Mountains, are represented by the folded and faulted ranges. The intermediate areas evidently were more stable and reacted as a solid shield. Recently the lowlands have suffered a transgression of the sea.

Lowlands

Only a few of the many small subcircular lakes dotting the surface of the Anadyr plain are distinct marine relicts; most of them are remnants of the channels of streams that once meandered across the plain. Afterwards, the lakes were transformed by processes of soil subsidence connected with the permanent congelation of the ground. This plain undoubtedly was recently occupied by the sea, and in some parts not far from the mountains—for instance, near the Zolotoi Mountains[18]—it has been glaciated.

The low plain of the Penzhina River is considerably smaller. It, too, is dotted with lakes; those that we had occasion to observe in the head of the valley are clearly marine relicts.

The Parapolski Dol is a valley about 50 kilometers wide and more than 350 kilometers long stretching between the Koryak and Penzhina mountains. To the northeast, by a pass at an elevation of a little more than 200 meters, it joins the somewhat higher lake plain of the Main River, a tributary of the Anadyr. To the south it connects with Bering Sea at Uala Gulf through the disruption in the Kamchatka-Koryak arc. In origin the Parapolski Dol is a depression lying in the folds of the Kamchatka-Koryak arc, but, when its large dimensions, its direct connection with the valley of the Main River, and the insignificant width of the Penzhina range are taken into consideration, it may be regarded as a part of the Anadyr depression.

Mountain Groups

Concerning the mountain groups of the Anadyr depression only a few salient facts need be pointed out. The general relationships are evident from the map. The Penzhina range,[19] a folded and faulted ridge, belongs to the system of the Kamchatka-

[18] Polevoi, *op. cit.*, p. 51; Cooper-Konin, Sklyar, and Kiryushina, oral communications, 1933.

[19] The name "Penzhina range" was used by Slyunin and fixed for this narrow chain by Bondarenko.

Koryak arc. Its wide south extremity is probably more complicated in structure than the narrow central and northern parts. The Nalgim and Russki mountains were formerly depicted as transverse ranges barring the Anadyr depression. The Nalgim, however, consist of a few irregular mountain clusters connected chiefly by recent effusives, and the Russki may be divided into two distinct groups. The west end of the Nalgim and the western group of the Russki belong to the Chuvan system (see above, p. 636). The eastern group of the Russki consists of low conical *sopkas*. The mountains west of the Berezovka in the area designated VI–6 on Figure 1 have no common name. In the south half of this region there are basaltic summits of tentlike and table-shaped forms. Farther north the ranges are for the most part finely dissected, with numerous peaked *sopkas*. The Rarytkin range, east of the Berezovka, is a recently folded and faulted branch of the Koryak Mountains and shows deeply dissected peaks and crests. The Pekulnei range is likewise folded and faulted. Many glacial lakes are found in its middle part, and on its west slope there is a hanging glacier.

Glacial History and Recent Continental Oscillations

The chronology of the vertical oscillations of northeastern Asia and the number of marine transgressions are not as yet precisely known, though for some regions interesting materials have been collected.[20] M. M. Ermolaev[21] determines for the New Siberian Islands three periods of uplift connected with the glaciation (the first one, with the largest glaciation, embraces the Pliocene only) and two transgressions in the periods between the glaciations. A. Grigorev[22] discovered in the Verkhoyansk Mountains numerous terraces up to 400 meters in elevation, which may be grouped into four pairs connected with as many glaciations. S. V. Obruchev, in all the districts he investigated, found terraces up to 350–400 meters in elevation, more than eight in all; nevertheless, he can distinguish only three glaciations, the first of which—the largest—occurred in the Pliocene.

For Chukchee Land evidences of only two glaciations have been collected, though further investigations may show traces of a greater number. It is well known that in Alaska, which has been much more fully explored, only the last Wisconsin glaciation has been well established, and there are only fragmentary data of the more ancient ones.

Thus we are able at present to state only that the entire northeast of Asia was subjected, during the post-Pliocene, to vertical pulsations common to the whole continent and that the absolute magnitude of

[20] A considerable part of northeastern Asia, including the Verkhoyansk and Okhotsk arcs and the Kolyma shield, was consolidated in the Upper Mesozoic to form a continental mass and since then has been subjected only to epeirogenic oscillations. The final coalescing of the eastern regions with the continental mass took place considerably later.

[21] M. M. Ermolaev: Geomorfologicheskii ocherk Novo-Sibirskogo Arkhipelaga (Geomorphological Sketch of the New Siberian Archipelago), *Trudy Soveta po Izucheniyu Proizvoditelnykh Sil*, Akademiya Nauk SSSR, Yakut Ser., No. 1, 1932, pp. 7–21.

[22] A. A. Grigorev: Geologiya, relef i pochvy sev.-zap. chasti Lensko-Aldanskogo plato i Verkhoyanskogo khrebta po dannym ekspeditsii 1925 g. (Geology, Relief, and Soils of the Northeastern Part of the Lena-Aldan Plateau and the Verkhoyansk Mountains According to the Findings of the Expedition of 1925), *Materialy Komissii po Izucheniyu Yakutskoi Avtonomnoi Sovetskoi Sotsialisticheskoi Respubliki*, Akademiya Nauk SSSR, No. 4, 1926.

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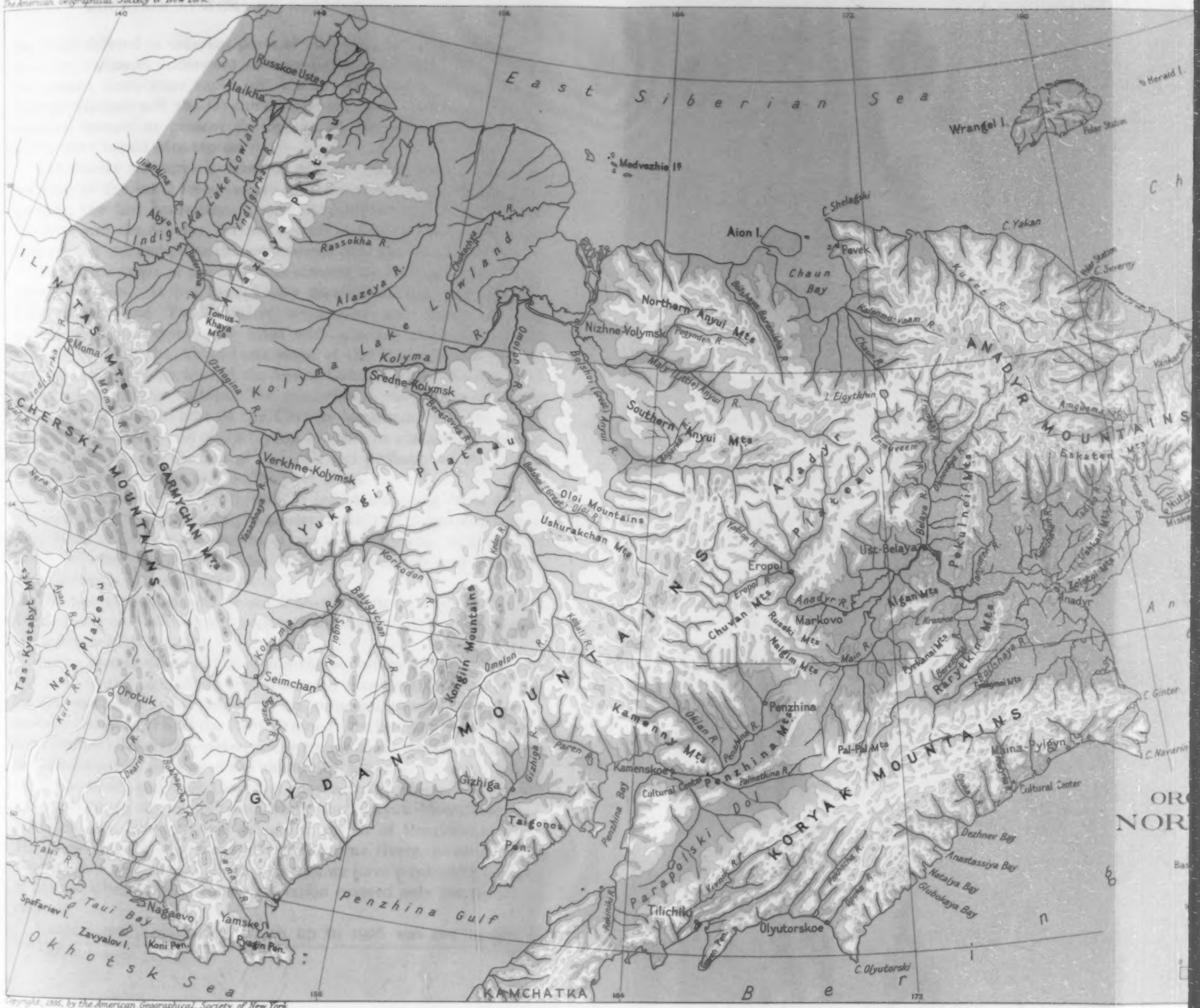
East Siberian Sea
Wrangel I.
Polar Station
Herald I.
Medvezhie Is
Russkoe Ustye
Alaikha
Abyo
Indigirka Lake Lowland
Indigirka R.
Yndigirka R.
Rassokha R.
Alazeya R.
Chukochya R.
Alazeya Lowland
Aion I.
Pevek
C. Shelagski
C. Yakan
Chaun Bay
Northern Anyui Mts
Nizhne-Volymsk
Pegymden R.
Malyi (Little) Anyui R.
Bolshoi (Great) Anyui R.
Southern Anyui Mts
Kolyma Lake Lowland
Kolyma R.
Omolon R.
Sredne-Kolymsk
Tomus-Khaya Mts
Moma R.
Ozhogina R.
Berezovka R.
Verkhne-Kolymsk
Yukagir Plateau
Oloi Mountains
Ushurakchan Mts
Yasachnaya R.
Korkodon R.
Ivdon R.
Balygychan R.
Kolyma R.
Seimchan
Orotuk
Nera plateau
Tas-Kystabyt Mts
Kulu R.
Dianrin R.
Taui R.
Taui Bay
Spafariev I.
Nagaevo
Yamskoe
Zavyalov I.
Koni Pen.
Begin Pen.
Okhotsk Sea
Penzhina Gulf
Taigonos Pen.
Gizhiga
Gizhiga R.
Penzhina Bay
Kamenskoe
Cultural Center
Penzhina R.
Palmatkina R.
Kamenny Mts
Oklan R.
Paren R.
Penzhina Mts
Pal-Pal Mts
Parapolski Dol
Tilichiki
Tilichiki R.
Vivenk R.
Olyutorskoe
C. Olyutorski
Olyutorski Pen.
Pakhachi R.
Vyvenka R.
Dezhnev Bay
Anastassiya Bay
Natalya Bay
Glubokaya Bay
Maina-Pylgyn
C. Navarin
C. Ginter
Cultural Center
KORYAK MOUNTAINS
Chuvan Mts
Markovo
Anadyr R.
Eropol
Eropol R.
Ust-Belaya
Belaya R.
Anadyr Plateau
Pekulnei Mts
Anadyr Mts
Runeski Mts
Nalgim Mts
Main R.
Krasnoe L.
Algan Mts
Pandanai Mts
Rarytkin Mts
Zelenyi Mts
Anadyr
Anadyr Bay
Anadyr Lowland
Anadyr Mountains
Eskaten Mts
Amguema R.
Vankarem
Kuvet R.
Kolymo-Vaam R.
Chaun R.
Pegymden R.
Bolshoi Baranikha R.
I. Elgytkhin
Enmyvaam R.
Tanyurer R.
Belaya R.
Ugolnaya R.
Tanyurer R.
Tanlan R.
Tanlan Mts
Zelenyi Mts
Anadyr
Anadyr Bay
Anastassiya Bay
Natalya Bay
Glubokaya Bay
Dezhnev Bay
C. Ginter
C. Navarin
C. Olyutorski
Olyutorskoe
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Cultural Center
Penzhina Gulf
Penzhina Bay
Penzhina R.
Palmatkina R.
Pakhachi R.
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Tilichiki R.
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Parapolski Dol
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Gizhiga
Gizhiga R.
Paren R.
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Cultural Center
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Penzhina Mts
Pal-Pal Mts
Oklan R.
Kamenny Mts
Omolon R.
Kolyma R.
Kolyma Lake
Kolyma Lowland
Kolyma R.
Omolon R.
Bolshoi (Great) Anyui R.
Malyi (Little) Anyui R.
Pegymden R.
Nizhne-Volymsk
Northern Anyui Mts
Bolshoi Baranikha R.
Chaun Bay
Chaun R.
Kolymo-Vaam R.
Kuvet R.
Polar Station
C. Severny
C. Yakan
Pevek
I. Elgytkhin
Southern Anyui Mts
Enmyvaam R.
Tanyurer R.
Belaya R.
Ugolnaya R.
Anadyr Plateau
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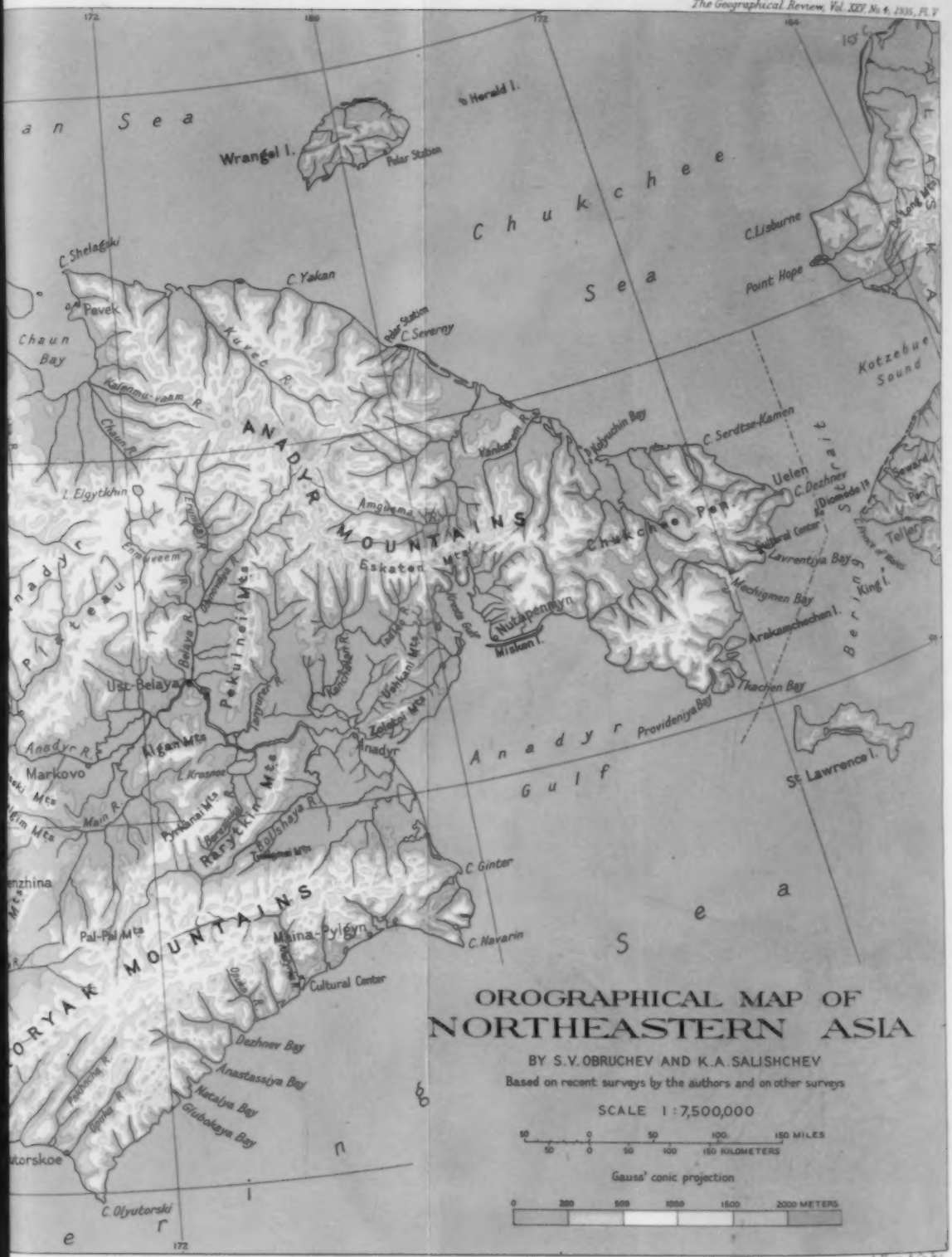
Eskaten Mts
Amguema R.
Vankarem
Anadyr Bay
Anadyr
Zelenyi Mts
Tanlan Mts
Tanlan R.
Anadyr Lowland
Anadyr Mountains
Ust-Belaya
Eropel
Eropel R.
Anadyr R.
Chuvan Mts
Markovo
Runeski Mts
Nalgim Mts
Main R.
Krasnoe L.
Algan Mts
Pandanai Mts
Rarytkin


Wrangel I.
Herald I.
Polar Station
Chukchee Sea
C. Shelagski
C. Yakan
Pevek
Chaun Bay
Kurupka R.
Kolymo-vaam R.
Chaun R.
C. Severny
Polar Station
C. Lisburne
Point Hope
Kotzebue Sound
Vankarem R.
Kolyuchin Bay
C. Serdtse-Kamen
Uelen
C. Dezhnev
Diomede Is.
Chukchee Pen.
Cultural Center
Lavrentiya Bay
Mechigmen Bay
Arakamchechen I.
Bering Strait
King I.
Teller
Nome
Nutapennyn
Miskan I.
Thachen Bay
Providenitya Bay
St. Lawrence I.
ANADYR MOUNTAINS
Amguema
Eskaten Mts.
Pekulnei Mts.
Ust-Belaya
Belaya R.
Anadyr R.
Markovo
Algan Mts.
Krasnoe
Main R.
Rarytkin Mts.
Anadyr
Anadyr Gulf
Zelotoi Mts.
Ushkani Mts.
Tanyurer R.
Yanrakinot R.
Tapka R.
Kraeve Gulf
C. Ginter
C. Navarin
Pal-Pal Mts.
Maina-Pylgyn
Cultural Center
Ukelayat R.
Dezhnev Bay
Anastassiya Bay
Natalya Bay
Glubokaya Bay
C. Olyutorski
Olyutorskoe
Penzhina R.
Upalon R.
Elgytkhin
Enmyveem
Yanrakinot R.
Kuruka R.
Kolymo-vaam R.
Chaun R.
Belaya R.
Tapka R.
Yanrakinot R.
Tanyurer R.
Anadyr R.
Main R.
Penzhina R.
Upalon R.
Ukelayat R.
Kraeve Gulf
Anadyr Plateau
Penzhina Mts.
Pal-Pal Mts.
Rarytkin Mts.
Zelotoi Mts.
Ushkani Mts.
Eskaten Mts.
Amguema
Elgytkhin
Miskan I.
Nutapennyn
Arakamchechen I.
Mechigmen Bay
Lavrentiya Bay
Cultural Center
Chukchee Pen.
Uelen
C. Dezhnev
Diomede Is.
Kolyuchin Bay
C. Serdtse-Kamen
Vankarem R.
Kotzebue Sound
Point Hope
C. Lisburne
Brooks Mts.
ALASKA
Teller
Nome
Bering Strait
King I.
St. Lawrence I.
Thachen Bay
Providenitya Bay
Anadyr Gulf
C. Navarin
C. Ginter
C. Olyutorski
Olyutorskoe
Dezhnev Bay
Anastassiya Bay
Natalya Bay
Glubokaya Bay
Cultural Center
Maina-Pylgyn
Pal-Pal Mts.
Rarytkin Mts.
Zelotoi Mts.
Ushkani Mts.
Eskaten Mts.
Amguema
Elgytkhin
Markovo
Algan Mts.
Krasnoe
Main R.
Anadyr R.
Belaya R.
Tapka R.
Yanrakinot R.
Tanyurer

the uplift differed in different parts of the land. The Cherski Mountains, for instance, underwent, and probably are undergoing even at the present time, more rapid uplift than the adjacent parts of the Yukagir plateau and the Gydan Mountains, as is evidenced by the erosional terrace at present developing on the Kolyma River and within the Cherski Mountains.

The marine transgressions in the different parts of the land have not been of the same force: whereas in the east, in the Anadyr depression, the last transgression entirely occupied the plains of the Penzhina and the Anadyr, farther north[23] and in the lowlands of the Kolyma and the Indigirka the sea covered only the coastal regions.

The greater part of the land was covered by ice during the maximum glaciation. It has been finally ascertained that the Cherski, Verkhoyansk, and Tas-Kystabyt mountains and nearly all the plateaus between them were filled with glaciers obviously of the icecap type. On the Aldan-Lena slope of the Verkhoyansk Mountains and on the slope toward the Sea of Okhotsk these glaciers were alpine and filled large valleys. The glaciation in the narrow and deep valleys of the middle part of the Cherski Mountains was the same. The maximum glaciation of the Gydan Mountains was similar—alpine on the slope toward the Sea of Okhotsk and probably of the icecap type in the middle part and on the west slope.

The thickness of the ice ranged, in individual cases, from 400 to 700 meters and the length of the glaciers from 150 to 300 kilometers. Their lower ends were at a height of 200 to 500 meters. It is not yet known whether the Kolyma shield with its plateaus and lowlands was filled with Quaternary glaciers.

The last glaciation was of much smaller extent, covering in the Verkhoyansk and the Okhotsk arcs only the highest parts of the ranges and separate high groups.

In the eastern parts of the region the boundary of the maximum, and even of the last, glaciation descended considerably lower. The glaciers undoubtedly occupied all the principal mountain groups—not only the Anadyr and the Koryak mountains but also the Rarytkin and Pekulnei chains and even such low groups as the Algan Mountains; they descended to the foot of the mountains, not more than 100 meters above sea level, and near the coast they acted similarly. There are fine fiords along the entire coast, along the Koryak Mountains, and in the Kresta Gulf, as well as in the region of Provideniya Bay. The large plains of the Anadyr and Penzhina rivers, however, were not occupied by glaciers. In this respect we have a complete analogy in Alaska, where the Wisconsin glaciation covered only the mountain systems.

Contemporary glaciation, which up to 1926 was not known to

[23] Ermolaev, *loc. cit.*

exist in the northeast, has been revealed in several localities. In the western district, which is low in precipitation, glaciers have been found only on very high ridges—in the Cherski range (on Mt. Chen, 3114 meters) and in the Kekh-Tas chain (2500 meters). Near Bering Sea, in a moister region, glaciers have been found on lower mountains —in the Pekulnei range (1500–1600 meters) at a height of 1300 meters, near the Kresta Gulf, and in the Eskaten chain (1500–1700 meters) at a height of 800–1000 meters.

The most important parts in the formation of the contemporary relief of the land were played by two factors of its newest history: the oscillating uplift of the continental massif and glaciation.

THE SO-CALLED BARTHOLOMEW COLUMBUS MAP OF 1506

John Bigelow

IN 1893 Freiherr R. von Wieser published a pamphlet[1] in which he attempted to show that certain sketch maps in a medieval codex[2] in the Biblioteca Nazionale at Florence were based on a map by Bartholomew Columbus dating from about 1506 that was subsequently lost. Although this theory had been suggested before Von Wieser's time, since then it has been widely accepted, and the sketch maps have been interpreted as directly reflecting the views of Christopher Columbus and his brother Bartholomew concerning the size of the earth and the general distribution of lands and seas.[3] In the following discussion evidence will be presented to show that the sketches do not represent Columbian ideas exclusively and probably date from as late as 1522–1525. In addition, several incidental points in Von Wieser's pamphlet will be subjected to criticism.

The Original Columbian Map

The opening sentence of Von Wieser's pamphlet may be translated thus: "On his fourth and last voyage [May 9, 1502–November 7, 1504] Christopher Columbus opened up (*entschleierte*) the coast of the mainland of Central America from the Gulf of Honduras to the Isthmus of Panama and plotted it (*nahm dieselbe . . . auf*) according to the rules of navigation with the aid of the magnetic compass."

As authority for these statements the author offers the following quotation from the great discoverer's report to the sovereigns of Spain, dated Jamaica, July 7, 1503, which for convenience may be called the "Christopher Report": "Segui la costa de la tierra firme: esta se asentó con compás y arte."

This is taken from the Spanish version in Navarrete's "Coleccion de los Viages."[4] Navarrete's version is a garbled copy of a copy in manuscript that until recently was in the private library of the King of Spain. What this copy in manuscript was copied from and when

[1] R. von Wieser: Die Karte des Bartolomeo Colombo über die vierte Reise des Admirals, reprint from *Mitt. Inst. fur österr. Geschichtsforschung, Ergänzungsband 4*, Innsbruck, 1893.

[2] Biblioteca Nazionale, Florence, Classe XIII, Cod. 81 (cited hereafter as "Classe XIII, Cod. 81").

[3] See, for example, G. E. Nunn: The Geographical Conceptions of Columbus, *Amer. Geogr. Soc. Research Ser. No. 14*, 1924, pp. 28, 58, and 66–68; Carlo Errera: L'epoca delle grandi scoperte geografiche, 3rd edit., Milan, 1926, pp. 335–336; Henry Vignaud: Histoire critique de la grande entreprise de Christophe Colomb (Études sur la vie de Colomb, Ser. 2), 2 vols., Paris, 1911, reference in Vol. 1, pp. 103–104; C. M. Dias and others: História da colonização portuguesa do Brasil, 3 vols., Oporto, 1921–1924, reference in Vol. 1, pp. liii and liv. See also below, p. 654.

[4] M. F. de Navarrete: Coleccion de los viages y descubrimientos, que hicieron por mar los españoles desde fines del siglo XV, 5 vols., Madrid, 1825–1837, reference in Vol. 1, p. 306; 2nd edit., 5 vols., Madrid, 1837–1880, reference in Vol. 1, p. 454.

it was copied are not known. Navarrete dates it from the middle of the sixteenth century; De Lollis, from the latter part of the seventeenth.[5] The original is lost, but there are several old, if not contemporary, copies of it, differing more or less from one another.

Von Wieser takes "esta se asentó" to mean "the latter was plotted (mapped, charted)." This may be implied; it is not expressed. The passage may be freely rendered: "I coasted the mainland, locating the latter (keeping my course or distance) by compass and seamanship." It has been put in these words: "I followed the coast of Tierra Firme; this I ascertained by the compass and my skill"[6]—here also without reference to a map or plot.

Had Von Wieser not gone out of his way for a Spanish version of the Christopher Report but drawn instead on an Italian one, which he had at hand in the Florentine codex to which reference has been made,[7] he would have had a more authentic text and better ground for his interpretation. This Italian text reads: "Seguitai la costa dilla tera ferma: questa si asiēto et misuro cō cōpaso et Arte[8] (I followed the coast of the mainland; this was located and measured by compass and skill [in triangulation?])." An editorial note in the margin says: "Mēsura optima (perfect, or exact, measurement)"—which at least suggests the plotting of a coast as well as of a ship's course.

On the basis of a passage in Las Casas' "Historia de las Indias" Von Wieser goes on to say: "The map of the newly discovered countries was made by the Admiral jointly with his younger brother Bartholomew, who accompanied him on this journey as *Adelantado* [governor] and captain of one of the ships. Bartholomew Columbus was known as an expert seaman, and in cartography was even superior to the Admiral."[9] The language of Las Casas does not warrant this encomium of Bartholomew Columbus as compared with his brother Christopher. Las Casas merely implies that Bartholomew may have been the better cartographer.

Telling of what he saw at Bishop Fonseca's in 1513, Peter Martyr says: ". . . quarum [nautae chartas] una à Portugalensibus depicta erat . . . . Alteri Colonus uiuens cum ea perlustraret loca dedit initium: cui et frater eius Bartholomeus Colonus Hispaniolae Adelantatus iudicium suum addidit: peragravit nanque et ipse ea littora[10] (. . . of which [nautical charts] one was made by Portu-

[5] Raccolta di documenti e studi pubblicati dalla R. Commissione Colombiana pel Quarto Centenario dalla Scoperta dell'America, 6 parts in 14 vols. and supplement, Rome, 1892–1896; reference in Part 1, Vol. 2, p. lxxxii.

[6] Cecil Jane, transl. and edit.: Select Documents Illustrating the Four Voyages of Columbus, Vol. 2, *Hakluyt Soc. Publs.*, Ser. 2, Vol. 70, London, 1933, p. 98.

[7] See footnote 2.

[8] Classe XIII, Cod. 81, fol. 61 r.

[9] Bartolomé de las Casas: Historia de las Indias, 5 vols., Madrid, 1875–1876; reference in Vol. 1, p. 224.

[10] Peter Martyr: De rebus oceanicis et orbe novo decades tres, Dec. II, Book 10, Basel, 1532, fol. 41 b; Paris, 1587, p. 173.

guese. . . . Another was begun by Columbus during his lifetime while he was exploring these regions, to which additions were made by his brother, Bartholomew Columbus, Governor of Hispaniola, for he too coasted these shores)."

From this testimony of Christopher Columbus, Las Casas, and Peter Martyr we may conclude that a plot, or outline map, was made by Christopher Columbus in the course of the voyage and that after the voyage, if not sooner, his brother coöperated with him in elaborating it into a finished map. We have no evidence that this was ever fully accomplished. It is not improbable that the work was going on when Christopher Columbus died, May 20 or 21, 1506, and that thereupon Bartholomew made from the unfinished joint map a possibly amended copy to take with him, as we shall see, to Rome. The joint map may have been unfinished when Peter Martyr saw it in 1513.

Character of the Original Map

Finished or unfinished, the joint map, we may be sure, was a typical example of the refined cartography of its time—not a mere nautical chart (delineation of coast line, islands, reefs, etc.), but a representation also of much of the hinterland. It is more than likely that notes and maps of other persons than the Columbus brothers went into it.[11]

When Columbus landed in Spain, returning from his fourth voyage (November 7, 1504), Queen Isabella had died. It does not appear that the King showed any interest in the map or that it was ever brought to his attention. We may assume that it was kept with jealous care by the Columbus brothers and their descendants, and we may imagine it eventually destroyed by some member of the family to keep it from the hands of a rival or competitor. At any rate it has not come down to us.

Aims and Purposes of Columbus

Von Wieser holds the common belief that the object of the coastwise cruise was to find a strait, that Columbus was looking for a way to Cattigara and the other flourishing ports and communities on the Indian Ocean.[12] This purpose has not been proved. It is a deduction apparently from another unproved theorem—that the object of Columbus on his first voyage was to find a route to the East, to China or India, by way of the west.

Columbus made four transatlantic voyages. The first two ended in the West Indies, the third on the continent of South America, and

[11] Evidence of the existence of such material is found in the testimony of Pedro Mateos, Juan Moreno, Gonzalo Díaz, and Alonso de Hojeda (Raccolta, Part 1, Vol. 2, pp. 222–224).

[12] Von Wieser, *op. cit.*, pp. 6 and 9.

the fourth not far from this continent, on the isthmus of Central America. Each of these voyages had as primary or secondary object the finding of gold. On the fourth voyage this was the primary object. A secondary object was to ascertain whether the land discovered on this voyage was connected with that which had been found on the third voyage; i.e. with South America. If Columbus was interested in water that might be found separating these lands, it was as a way, not to China, India, or any other old and settled country, but to an undiscovered or unclaimed one that he might appropriate in the name of his sovereigns and administer and exploit by the authority that he had received from them as their viceroy. His letter of instructions, dated March 14, 1502, reads in part as follows:

> You will take a straight course . . . to discover the islands and mainland that are in the Indies in the region accruing to us, . . . you will take possession for us and in our name of the said islands and mainland that you may thus discover, and will inform yourself of the size of the said islands, and will take notes on all of the said islands [on their size and location], and on their population and the quality thereof, in order that you may bring us a detailed report on the whole subject.
>
> You will see in these islands and [the] mainland that you may discover, what gold and silver and pearls and [precious] stones and spices and other things may be there, [noting] in what quantity [and] how they are generated, and [will] draw up a report on this whole matter before our notary and agent (*escribano é oficial*) whom we are sending with you accordingly . . . [13]

In this letter and in the Christopher Report there is not a word about a strait.

Evolution of the Map

Von Wieser, in his pamphlet, furnishes in facsimile three sketch maps, which he calls "a rough copy of the joint map (*eine—wenn auch mangelhafte—Copie jener wichtigen, bis jetzt vermissten Karte*)."[14] He calls attention to two documents forming part of the Florentine codex mentioned above. This codex is a volume of manuscript and printed matter compiled by a certain Alessandro Zorzi. Both documents are accounts of the fourth voyage. One is ostensibly an informal report by Bartholomew Columbus; the other is a copy of the Christopher Report and is illustrated by the three sketch maps. The former document is not really by Bartholomew Columbus. It is a memorandum of his report, in the form in which Zorzi received it, not directly from its reputed author but, as we shall see, at second hand. Let us call this the "Zorzi Memorandum." The original Bartholomew Columbus document was apparently a report only in name and consisted of a map set off with descriptive notes.[15] Let us call this map, with its notes, the "Bartholomew Map."

[13] Navarrete, *op. cit.*, 1st edit., Vol. 1, p. 279; 2nd edit., Vol. 1, p. 427.
[14] Von Wieser, *op. cit.*, p. 8.
[15] Classe XIII, Cod. 81, fol. 31 r; Von Wieser, *op. cit.*, p. 10.

Although the text of the Christopher Report makes no mention of a map, the sketch maps illustrating Zorzi's copy of it[16] are presented by Von Wieser as a reproduction of our joint map, on the triple assumption: (1) that these sketch maps are a reproduction of the Bartholomew Map; (2) that the Bartholomew Map was made by Bartholomew Columbus; and (3) that the Bartholomew Map, made by Bartholomew Columbus, was virtually a reproduction of the map made by Christopher Columbus together with Bartholomew Columbus—the joint map.

These propositions are based on a few sentences in the Zorzi Memorandum.[17] Before examining these sentences, however, let us look into their authorship.

Alessandro Zorzi

For years it was a matter of discussion whether the compiler of the manuscripts in our codex was Alessandro Strozzi of Florence or Alessandro Zorzi of Venice. The question may now be considered as settled in favor of Zorzi (Venetian form of Giorgi).[18] He is represented as a precursor of Giovanni Battista Ramusio and as less known only because his work was never published. Compared with Ramusio, he might rate as an amateur beside a professional. A close examination of his pages shows him to be capable of poor work. The writing is so bad that it may be safely said that no two readers will make out the spelling alike. At the same time he was no dilettante. His manuscripts show him to have been deeply interested in geography, and his roughest maps exhibit a serious concern for definite and correct graduation (longitude and latitude). He collected accounts of voyages, taking down many himself from the mouths of returned travelers, copying others from manuscript or printed texts, borrowing others in print directly from books. In the Biblioteca Nazionale in Florence they now form four volumes or codices in Classe XIII. They were apparently intended for private and personal use; at any rate, they were not put in shape for publication. One can hardly infer from them that Zorzi was especially interested in the New World. Only one of his four extant codices—80, 81, 83, and 84—is devoted to that subject, codex 81.[19]

As to the period in which Zorzi lived, it appears that "in the latter part of the fifteenth century he made an excursion in Greece and penetrated the interior of Egypt, in quest of useful knowledge and ancient relics."[20] This fact and the dates in his manuscripts make it

[16] Classe XIII, Cod. 81, fol. 54 r.

[17] *Ibid.*, fol. 31 r.

[18] Laura Mannoni: Notizie sull'Etiopia raccolte da uno studioso veneto del secolo XVI, *Boll. R. Soc. Geogr. Italiana*, Ser. 6, Vol. 9, 1932, pp. 603–620; references on pp. 603–604 and 619.

[19] There was originally a fifth codex, 82, which is lost.

[20] Mannoni, *op. cit.*, p. 604.

probable that he was born early in the second half of the fifteenth century and died late in the first half of the sixteenth; also that when Columbus returned from his first voyage, and reports of it began to circulate, Zorzi was already an amateur, if not a scientific, geographer.

Report and Map by Bartholomew Columbus

Von Wieser gives the full text of the Zorzi Memorandum, or ostensible report by Bartholomew Columbus, as Zorzi rendered it. He gives it in print without an accompanying facsimile in Zorzi's handwriting. In commenting on the pertinent passages, he learns from them, he says (italics mine)

> . . . that Bartholomew Columbus, soon after the death of the Admiral, had brought a *map and description* of Veragua to Rome, where he sought the intervention of the Pope to impel the Spanish court to equip a new expedition for the *colonization* and Christianization of the lands discovered by himself together with his brother. Bartholomew Columbus then sent to a Brother Jerome [frate Hieronimo], canon of St. John's in the Lateran, "di sua [*sic*] mano uno disegnio de' litti di tal terre, dove eran [*sic*] descripte i lochi, la conditione et natura et costumi et abiti di quelli popoli." This [same] Brother Jerome later turned over the [Bartholomew] map, together with the description, to Alex. Strozzi [Zorzi] . . . [21]

The first sentence intimates that the map and the description formed one document as indicated in the following passage, second sentence, by the words in Italian that Von Wieser quotes from the Zorzi Memorandum (Von Wieser's text; italics mine):

> Del 1505 essendo Bartolamio [*sic*] Colombo fratello di Christophoro Colombo da poi la sua morte andato a Roma per haver lettere del pontifice al Re di Spagna chel volesse esser contento di darli caravelle in ordine di quel bisognava et specialmente di frati docti in philosophia et Theologia et in la sacra scriptura et questo perchè si oferiva ritornare alle terre dil mondo novo dove insieme con ditto suo fratel havea del 1503 discoperte per ponente a Garbin di la dalla Spagnolo da miglia 3000 et trovato le mine del Oro in Beragna et altri lochi dove con facilità si converteria con facilità tanti popoli alla fede cristiana con honor et utile. Di che ditto Bartolomeo confesato da uno frate Hieronimo de lordine [*sic*] di frati canonici regulari in S. Joanni Lateran *li dete di suo mano* uno disegnio dè [de, de'] litti di tal terre dove eron [erō, erano] discripte i lochi la conditione et natura et costumi et abiti di quelli popoli et esendo ditto frate Hieronimo qui in Venetia . . . mi dette el tal disegno et el simile mi dette in scripto la conditione et popoli di tal paesi li quali in brieve Jo Alex°. Strozi [Zorzi] li noterò . . . [22]

There is nothing here about colonization. Von Wieser's mention of it is an interpolation. He apparently misunderstood the words "li dete di suo mano uno disegnio" to mean "gave him a map drawn by his own hand." The real meaning is that he gave him a map with his own hands, or handed him a map. As far as our text shows, it may or may not have been drawn by Bartholomew Columbus. Von

[21] Von Wieser, *op. cit.*, p. 4.
[22] *Ibid.*, pp. 10–11.

Wieser would seem to imply that the map was drawn by Bartholomew Columbus and reproduced by Zorzi in illustration of the Christopher Report. He says in another connection:

> As we now know that the compiler [Zorzi] had a map of Bartholomew Columbus, covering (*über*) the fourth voyage of the Admiral, it can hardly be doubted that in these offhand sketches [added by Zorzi to the Report] we have a copy—albeit defective—of that important and hitherto missing map.[23]

There is no indication in these sketches that they are a reproduction either of the lost Bartholomew Map or of the joint map. We may assume that the Bartholomew Map, by whomsoever made, was based on the joint map but that it differed from it: (1) as a map for religious propaganda would differ from one for commercial exploitation; (2) as an up-to-date map would differ from a somewhat obsolete one. This raises questions of time and date, which will be discussed later.

The Zorzi Memorandum

Von Wieser's assertion that Brother Jerome later turned over the Bartholomew Map, *together with the description*, to Alexander Strozzi (Zorzi) would make the map and the description two separate documents. This is apparently an error due to the confusion of two statements in the Zorzi Memorandum—the statement concerning the document handed to Brother Jerome and the following one concerning documents given by Brother Jerome to Zorzi. This second statement, which comes at the end of the passage quoted on the opposite page, may be translated thus: "The said Brother Jerome, being here in Venice . . . , gave me that map and also gave me in writing a description of the condition and of the people of that country, which I, Alex. Strozi [Alessandro Zorzi], will briefly set forth."

Here the map is identified as our Bartholomew Map, but the description in writing is not identified. What was this document given to Zorzi by Brother Jerome but not mentioned as having been given to Brother Jerome with the map? Was it made by Bartholomew Columbus or by Brother Jerome? Was it the Christopher Report? As it was furnished by Brother Jerome, let us call it the "Jerome Description." The original is lost. Not even a copy of it has come down to us; for Zorzi's memorandum is admittedly an abridgment and therefore more or less a paraphrase of it. As such this memorandum may be regarded as an original document. Its language is not clear as to how far Zorzi was guided, in writing it, by a text before him or how far by his memory and imagination. Von Wieser says, without proving it (italics mine): "Alex. Strozzi prepared *then*, for his collection, a *draft from the text* of Bartholomew Columbus [the Jerome Description], retaining in part the first person."[24]

[23] *Ibid.*, p. 8.
[24] *Ibid.*, pp. 4–5.

It appears from the context that the word "then" means when the map and description were received by Zorzi from Brother Jerome. How long was this after Brother Jerome received the Bartholomew Map (1506)? Von Wieser does not say; he simply says "later (*später*)."[25] Zorzi is hardly less vague, saying that it was while Brother Jerome was in Venice. This leaves us free to suppose a considerable interval between the receipt by Brother Jerome and the receipt by Zorzi. But was it even on his receipt of the description that Zorzi made his memorandum? His language as quoted above (p. 648) is not clear on that point. It admits of a considerable interval between his receiving the description and his transcribing it.

The Zorzi sketches were based undoubtedly in part on the Bartholomew Map given to Zorzi by Brother Jerome, probably in part on the Jerome Description, and possibly in part on other sources. They could not have been based to the slightest extent on the Zorzi Memorandum, which was not made until long afterwards.

The phrase "retaining in part the first person (*theilweise unter Beibehaltung der persönlichen Redeweise*)" implies the use of the first person in the Jerome Description and consequently that this was a description, not merely of a country and its inhabitants, but of a voyage; in other words, a narrative, or relation. On this assumption Zorzi appears to have departed from the text to the extent of representing the coastwise voyage as from south to north, instead of correctly from north to south.[26] To explain this Von Wieser infers "that the text of Bartholomew Columbus [the Jerome Description] was not a real narrative of a voyage, but a description of the coast and its inhabitants, which—although in strict accordance with the map—happened to begin at the southernmost point reached, which [description] was misunderstood [mistaken for a narrative] by the compiler [Zorzi]."[27] This is contrary to the implication that the Jerome Description was a narrative.[28] Zorzi's mistake could not have been made by either of the Columbus brothers or by any intelligent companion of theirs, notwithstanding the occasional appearance in the Zorzi Memorandum of the first person plural. Las Casas, in his rendering of Christopher Columbus' journal of his first voyage, uses both the first and the third persons.

The Jerome Description was not based on the Christopher Report; for in that case it would not have contained the concluding reference to Columbus recorded by Zorzi (my translation): ". . . they [members of the expedition?] said many more things, which I do not state, because by the letter that Christopher Columbus, his brother,

[25] *Ibid.*, p. 4.
[26] *Ibid.*, pp. 11–13.
[27] *Ibid.*, p. 5, footnote 2.
[28] *Ibid.*, pp. 4–5.

has written to the King of Spain [the Christopher Report] you were informed of it."[29]

It is probable that Zorzi was turned around by an indiscriminate use of maps having the north at the top and maps having the south, and of texts based on them. Most of his maps have the north at the top, but on his largest map of the world,[30] which has the south at the top, he has the archipelago of the Moluccas with Borneo and Celebes upside down, or with the north at the top.[31]

Report by Christopher Columbus; The Zorzi Sketches

Turning to Zorzi's copy of the Christopher Report, we find it entitled (my translation): "How Columbus sailed west and coasted India from the equator toward the north pole and reached the Kingdom of China."[32] This title, representing the discovering of Central America as having taken place from south to north, could not have been furnished by Christopher or Bartholomew Columbus. Perhaps the Report came to Zorzi without a title and in giving it one he turned it topsy-turvy for the reasons just explained.

Von Wieser reproduces the sketch maps in the Report in actual size, designating them as Plate (*Tafel*) I, Plate II, Plate III. I designate them in the order in which they appear in the codex as Sketch A (folio 56 v.), Sketch B (folio 57 r.), Sketch C (folio 60 v.). Von Wieser gives Sketch C on Plate I, Sketch B on Plate II, and Sketch A on Plate III. Why he does not present them in the order of their sequence in the codex is a question. Had he done so, he might have escaped the blunder of taking them to be, or trying to make them, parts of one and the same map. Sketches A and B represent the known world as located between 20° W. and 205° E. of the Canary Islands.[33] The two sketches coincide or join on their 80th meridian. Let us call them together Sketch AB. The three sketches are thus reduced to two: Sketch AB (Fig. 1) and Sketch C (Fig. 2).

Von Wieser calls the sketches *Randzeichnungen*, marginal drawings, implying thereby that they were added after the text was written. The dimensions of his plates make this designation questionable. An examination of Sketch B (folio 57 r.), in comparison with the pages in general, proves the drawing to be not marginal but in the text and consequently contemporary with the text. This conclusion may reasonably be extended to Sketches A and C. The content of Sketch B shows that Sketch AB is, in the main, an illustration of Ptolemy's geography as extended by the discovery of America and of the route

[29] *Ibid.*, p. 13.
[30] Classe XIII, Cod. 81, fols. 153 r.–157 r.
[31] *Ibid.*, fol. 155 r.
[32] *Ibid.*, fol. 54 r.
[33] Named Madeira Islands on Sketch A but Canary Islands on the more carefully drawn Sketch C.

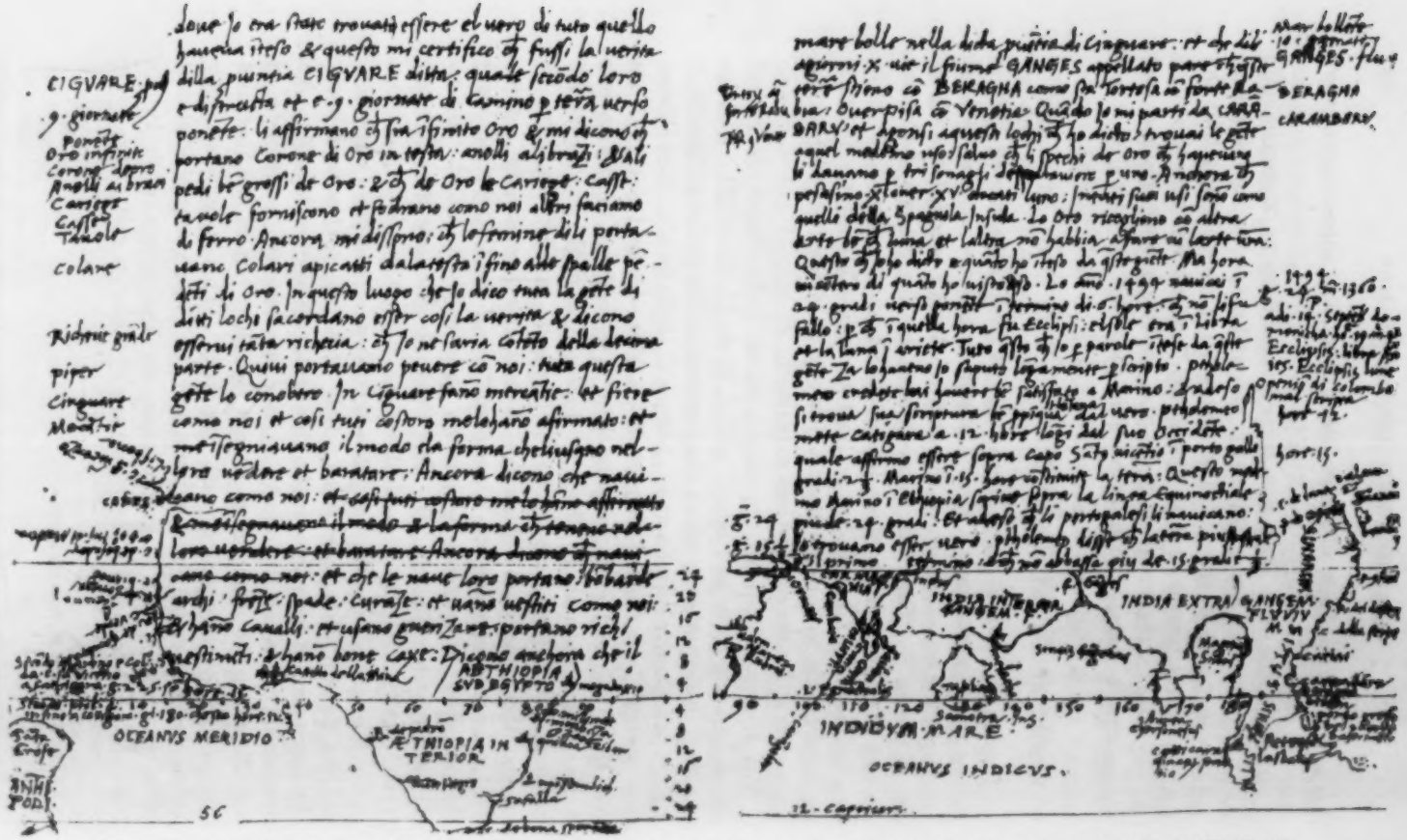


FIG. 1.—Two pages from manuscript by Alessandro Zorzi (Biblioteca Nazionale, Florence, Classe XIII, Cod. 81, fols. 56 v. and 57 r.) showing Sketch AB.

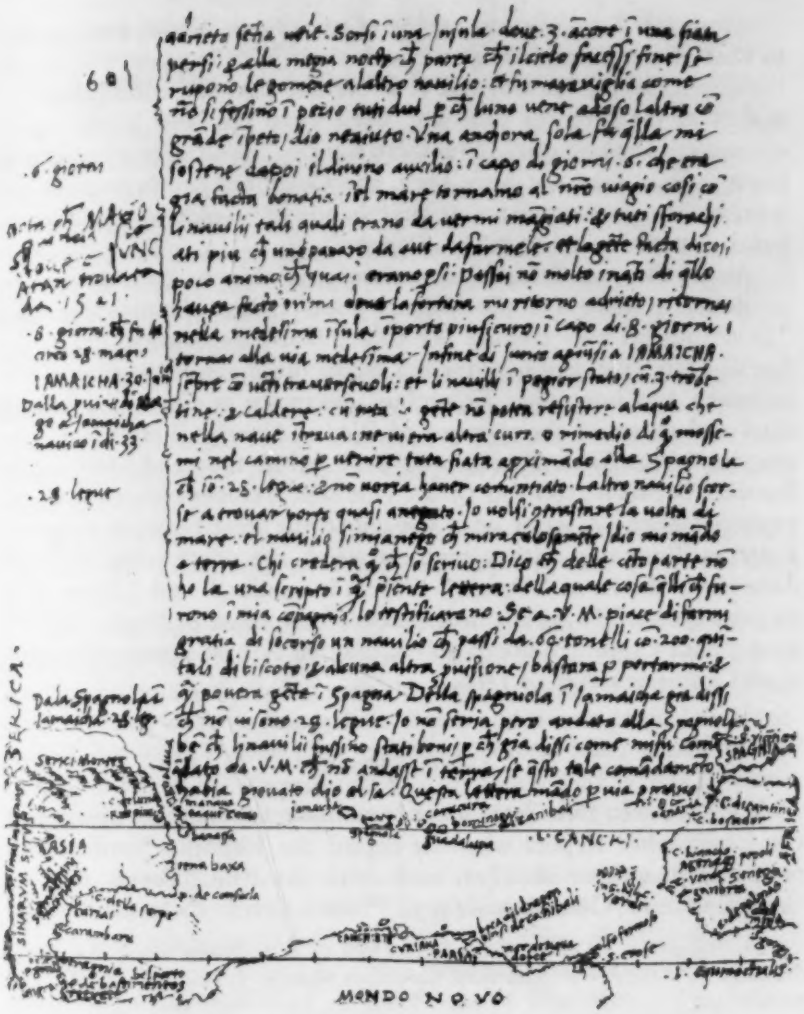


FIG. 2—Page from manuscript cited in caption to Figure 1 (fol. 60 v.) showing Sketch C.

around the Cape of Good Hope and altered by the elimination of Ptolemy's "Terra incognita" south of his Indian Ocean. Sketch C shows it to be simply Zorzi's conception of the Atlantic Ocean and parts of its western boundary as discovered by Columbus and other navigators. It may be considered as devoted to the New World, but neither of the sketches is given up to Columbus' last voyage alone. Sketch AB, on the other hand, is devoted, as was Zorzi's work in general, to the whole world. The break, or hiatus, extending eastward from about 205° E. to about 20° W. of the Canary Islands (about 135 degrees) may be attributed to want of space on the folios.

How far Zorzi's cartography of the New World corresponded to that of the Columbus brothers on their joint map, or was derived therefrom, is not known, but it is certain that the conceptions embodied in the sketches were not, even as to the New World, drawn exclusively from original Columbian sources. Whatever other sources there may or may not have been, the Columbus brothers could not, from their own knowledge at first hand, have plotted the coast of South America to about 30° S. (Sketch C).

As to the non-Columbian sources available to Zorzi in making his sketches, there is ample evidence in our codex. An article entitled "Descriptio di cose trouate per Castigliani ĩ un discorso dal 1500 ĩ fino al 1510 da diuersie caravelle ĩ questi diece anni"[34] begins with a reference to Christopher Columbus' discovery of South America in 1498 and treats of the voyages of Ojeda (Amerigo Vespucci accompanying him), Niño, Pinzón, and Lepe, all in 1499 and 1500, and of Bastides between 1500 and 1510. This article comes before the Christopher Report. A letter on a voyage to the East between 1503 and 1505[35] is illustrated with a map on which the north coast of South America is shown as "Brasil," "Terra incognita," and "Terra vista da portogalesi."[36] Zorzi's delineation of the coast of South America from "Scta Crose" to about 30° S. (Sketch A) was apparently taken from Contarini's map of 1506.

Chronology

We have seen that Zorzi must have made the sketches illustrating the Christopher Report when he copied the Report. Nordenskiöld published the three sketches, each with the title "Sketch map by Bartholomaeus Columbus (1503)"[37] and listed them as follows:

> 22. (1503.) . . . Three sketch-maps which Fr. R. v. Wieser found as marginal drawings on a copy of a letter from Columbus when in Jamaica, dated July 7th, 1503. . . .

Nordenskiöld thus represents the original map as made by Bartholomew Columbus on the fourth voyage or from data available at the time of the voyage.

Denucé represents the sketches (*esquisses*) of Bartholomew Columbus as made in 1504.[38] In a list of maps forming an appendix to a historicogeographical study published in Italy in 1866 is the item:

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[34] Classe XIII, Cod. 81, fol. 42 v.

[35] Classe XIII, Cod. 84, fols. 161 r.–184 r.

[36] *Ibid.*, fol. 169 v. 170 r.

[37] A. E. Nordenskiöld: Periplus, translated from the Swedish original by F. A. Bather, Stockholm, 1897, pp. 167–169 and 178.

[38] Jean Denucé: Magellan: La question des Moluques et la première circumnavigation du globe, *Mémoires Acad. Royale de Belgique, Classe des Lettres et des Sci. Morales et Polit.*, Ser. 2, Vol. 4, Brussels, 1911, pp. 42 and 87, footnote 1, and plate opp. p. 42.

Anno 1505. Carte di Bartolomeo Columbo . . . Nel Secolo XVI erano a mani del Veneto cosmografo Zorzi[39] (Year 1505. Maps of Bartholomew Columbus . . . In the 16th century they were in the hands of the Venetian cosmographer Zorzi).

Von Wieser confines his discussion of date to the question of Bartholomew Columbus' sojourn in Rome. The date of this occurrence is given in the Zorzi Memorandum as "In 1505 . . . after the death of Christopher Columbus."[40] Von Wieser says: "This designation of the year is incorrect, since Christopher Columbus . . . died on the 21st [or 20th] of May 1506. The sojourn of Bartholomew in Rome must have been between 1506 and 1508."[41] As authority for these dates he cites Harrisse.[42]

If the reader will turn to the facsimile, Sketch C (Fig. 2), and run his eye down the left-hand column, he will come upon the notation: "Nota che Mago provincia si e doue e Iuncatan trouato da 1521[43] (Note that the province of Mago [Mangi] is in the territory of Yucatan found in 1521)."

This marginal note was, to all present appearances, contemporary with the rest of the document and so makes the date of our sketches 1522 or later.

The documents in our codex follow one another in about the chronological order of their topics, beginning with the discovery of America in 1492 and ending with the conditions there in 1538. From this fact, from what we know about Zorzi, and from a critical examination of his papers with their occasional extra date, apparently of receipt, it seems not unreasonable to conclude that it was in about their present order that the documents composing this codex were received and compiled.

The absence from the sketches of all indication of the shape of the South American continent and the absence from the Christopher Report and preceding documents of all mention of Magellan or of his voyage may be taken to prove that the sketches were made in ignorance of the discovery of the Strait of Magellan. That event became known in Europe in 1522. The strait is shown on an anonymous map printed in Rome in 1523, a manuscript copy of which is in our codex. This copy bears a legend by Zorzi referring to "pedra de Villa" on October 8, 1524,[44] the date of a report by "de Villa" to the Spanish sovereign. Zorzi's copy of this report[45] is headed with the date 1525. As this is probably the approximate date of Zorzi's tran-

[39] Allegata I, *Atti Soc. Ligure di Storia Patria*, Vol. 4, Genoa, 1866, pp. clxviii and ccxlii-ccxliii.

[40] Von Wieser, *op. cit.*, p. 10.

[41] *Ibid.*, p. 10, footnote 1.

[42] Henry Harrisse: Christophe Colomb (Recueil de voyages et de documents pour servir a l'histoire de la géographie, 6, 7), 2 vols., Paris, 1884, reference in Vol. 2, p. 206; *idem:* The Discovery of North America, London and Paris, 1892, p. 437.

[43] Yucatan was discovered before 1521, but this is immaterial in the present discussion.

[44] Classe XIII, Cod. 81, fol. 154 r.

[45] *Ibid.*, fol. 157 v.

scription of the report, we may also take it as about the date when Zorzi made his copy of the map and added the legend to it. It is thus the latest date at which Zorzi could have been ignorant of the Strait of Magellan. This makes the date of our document 1522–1525.

According to the evidence available, this is the approximate date, not of the Bartholomew Map, which as the work of Bartholomew Columbus may never have existed, but of the sketch maps by Alessandro Zorzi, which are still extant and which Bartholomew Columbus never saw.

Summary

I am in substantial agreement with Von Wieser in crediting the Columbus brothers with the joint production of a map about the time of the fourth voyage.

I disagree with him about the map that Bartholomew Columbus took with him to Rome. He represents it as a copy, I regard it as a revision, of the joint map.

He believes that the copy, I believe that the revision, was transmitted in Rome to Zorzi by Brother Jerome.

Von Wieser holds that the sketches are a reproduction of the copy.[46] I regard them as original work based in part on the revision but mostly on other data.

He regards the sketches as an exposition of Columbian geography between 1503 and 1506. I see in them the geographical notions of Alessandro Zorzi about twenty years later, some of them derived from the Columbus brothers.

He calls the sketches marginal drawings. I say that they are in the text.

He considers them as parts of one map. I make them parts of two maps.

He asserts or implies that the map that Bartholomew Columbus gave to Brother Jerome was accompanied by a description as a separate document and that both the map and the separate description were transmitted by Brother Jerome to Zorzi. I find no evidence of a separate description accompanying the Bartholomew Map, and I assume that the description given by Brother Jerome to Zorzi was more or less based on the Bartholomew Map but did not originate with the Columbus brothers.

[46] Von Wieser, *op. cit.*, pp. 8–9.

CONTINENTAL PRECIPITATION ON A ROTATING EARTH

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ANY textbook that deals with climatologic matters will inform its readers that air flows from the sea into the interior of continents that are warmed in summer to the extent of imparting to the air above them a temperature higher than that of the air above adjoining seas. The same textbook will convey the further information that as one goes inland in North America from the Atlantic or the Gulf of Mexico, or in Europe eastward from the Atlantic, the annual total of precipitation decreases because the water vapor of maritime air is progressively condensed out as the air moves inland, so that in the far interior of a continent it arrives dry and hence incapable of yielding much precipitation. On one question, however, the textbook is silent: why this reason for a decrease in precipitation inland is so obviously applicable to North America and most of Eurasia, to South Africa and the southern half of Australia, while the very phenomenon it explains is not to be observed in the tropical parts of South America and Africa. Distance from the sea has little effect on the amount of precipitation in the two last-named regions: the headwaters of the Amazon and the Nile are fed by annual totals of precipitation unknown to the sources of the Mississippi and the Ob.

Influence of the Earth's Rotation

Once this difference between the interiors of continents in the tropics and in higher latitudes is pointed out, the general principles governing the circulation of the atmosphere on a rotating earth provide an immediate explanation. Near the equator a difference in temperature between air over land and air over adjacent sea gives rise to a compensating circulation in which maritime air may move without hindrance, except by the accidents of relief, directly into the heart of a continent. Similarly, if a contrast in air temperature arises between different parts of a continent, the compensating circulation between cooler and warmer areas may proceed freely. Outside the tropics, on the contrary, a contrast in temperature between land and surrounding sea gives rise to a circulation about the land that is in general terms cyclonic if the land is warmer than the sea, anticyclonic if the land is cooler. The earth's rotation is an obstacle to the free ingress of maritime air to the parts of the continents remote from the sea. Maritime winds that would proceed without delay into the interiors of large land masses in the tropics penetrate continents in

higher latitudes only intermittently and with decreasing frequency the farther inland. Our precipitation maps reflect the decrease in frequency of maritime air inland in a parallel decrease in density of the colors representing amount of precipitation.

Given the qualities of maritime and continental air, the distribution of precipitation over the continents is thus an expression of the character and intensity of the atmospheric circulation about and over them. In the following the distribution of precipitation over the lands will be called "peripheral" where the seasonal or annual amount decreases continuously—with due allowance for relief—inland from the coasts. It will be called "continental" where increasing remoteness from the sea is not accompanied by a proportional decrease in the seasonal or annual total. Peripheral distribution is characteristic of extratropical latitudes, continental distribution of tropical latitudes.

A dynamic interpretation of the distribution of continental precipitation shown on maps of annual, seasonal, or monthly totals has as a prerequisite a more precise definition of the latitudes in which it occurs than has been formulated above. Our familiar concept of tropical latitudes is founded on the angle of inclination of the earth's axis to the plane of the ecliptic. In the present connection this quantity is of no significance. The control exercised over moving masses of air by the rotation of the earth is a function of (*a*) the rate of rotation of the earth about its axis, (*b*) the linear velocity of the air, and (*c*) the sine of the latitude in which the motion is taking place. The first of the three terms is a constant. In an estimate of the effectiveness of the earth's rotation in limiting free advection we may use any plausible values of wind velocity and pressure gradient. The sine term varies with the latitude: zero at the equator, it increases at its most rapid rate within the first few degrees of the equator, and at latitude 30° attains half the value it has at the poles. To designate on theoretical grounds a certain latitude at which the earth's rotation assumes control over the circulation of the atmosphere and hence over the distribution of precipitation is obviously impossible, since its effect increases continuously from the equator poleward.

Pressure Gradients and Wind Velocities

An estimate close enough for comparison with rainfall data may, however, be deduced from the relation of pressure gradient to the wind velocities that may be expected to arise from local or regional differences in air temperature. This relation is defined by the classic equation for steady frictionless wind, the principal terms of which were enumerated above. The equation says that wind velocity and steepness of pressure gradient are proportional, and that the wind blows parallel to the isobars, having low pressure to the left of its

direction of movement in the northern hemisphere, to the right of its direction of movement in the southern. With straight isobars the pressure gradient is just balanced by the deflective force of the earth's rotation.[1] The original derivation of the equation and the manner in which it has most frequently been discussed imply that pressure gradient is the independent variable, hence that the movement of air results from the pressure gradient. The reason for this manner of presentation is to be sought in the origin of dynamic meteorology in hydrodynamic theory and in the almost exclusive concern of synoptic meteorology, through most of its history, with the distribution of atmospheric pressure. But once the equation is set up in unexceptionable form it is permissible to turn it about and thereby to make it say that frictionless wind of a given velocity and direction gives rise to the pressure gradient defined by the reversed equation. It is only necessary to derive wind from density gradient rather than from pressure gradient, as does the Bjerknesian analysis of the origin of circulation in the atmosphere,[2] in order to liberate wind from its conceptual dependence on pressure gradient; and then pressure gradient may be derived from direction and velocity of wind. Sir Napier Shaw has proceeded from this viewpoint in writing the fourth volume of his "Manual of Meteorology." He announces prefatorily that in this volume "pressure-gradient, stabilised by the persistence of horizontal motion on the rotating earth, appears as a static index of the motion. It is not regarded as a source of energy apart from that indicated by horizontal differences of entropy"; and, further, that "motion has taken the place of pressure as the 'independent variable' in the gradient equation, that is to say the pressure-distribution is regarded as the 'banking' required for the maintenance of the air-currents."[3]

Circulation Over Pacific Coastal Region of the United States

The chain of physical processes involved in Shaw's adaptation of the logic of the gradient equation is not difficult to imagine. Consider, for example, the Pacific coastal region of the United States in summer. The heating of the air over the cloudless interior of the land produces in the lower atmosphere a steep density gradient from the ocean toward the land. On a nonrotating earth, or near the equator

[1] The derivation of the equation is to be found in any work on dynamic meteorology; for example, H. C. Willett: Dynamic Meteorology, *in* Physics of the Earth—III: Meteorology, *Bull. Natl. Research Council No. 79*, 1931, pp. 133–233, reference on pp. 178–182; David Brunt: Physical and Dynamical Meteorology, New York and Cambridge, 1934, pp. 181–189.

[2] V. Bjerknes: Das dynamische Princip der Cirkulationsbewegungen in der Atmosphäre, *Meteorol. Zeitschr.*, Vol. 17, 1900, pp. 97–106 and 145–156, reference on pp. 145–156; *idem:* The Dynamic Principle of the Circulatory Movements in the Atmosphere, *Monthly Weather Rev.*, Vol. 28, 1900, pp. 434–443; Willett, *op. cit.*, pp. 170–175.

[3] Sir Napier Shaw, with the assistance of Elaine Austin: Manual of Meteorology, Vol. 4, Cambridge, 1931, pp. vii and viii.

on the earth as it is, this density gradient would be balanced by an acceleration of the air in the coastal zone toward the land. But in latitudes 30° to 45° the rotation of the earth controls the movements of air. The incipient gravitational flow toward the land suffers deflection to the right and so first becomes a movement parallel to the coast and then, if the pressure gradient from sea to land is not enough to prevent further deflection, continues as a return movement to the sea. Air movement from sea to land along the density gradient is checked by the rotation of the earth, so that above the layer of air affected by the resistance offered to its movement by the ground there is no opportunity for air on the cool side of the system to escape to the warm side. On the other hand, as long as the density gradient is becoming steeper, and hence the circulation becoming more intense, as in early summer when temperatures over the land are rising rapidly, air is constantly being thrust by deflection from the warm to the cool side of the system. Transfer of air from land to sea lowers pressure over the land and raises pressure over the sea and so builds up a pressure gradient.

As the temperature of the air over the land reaches its maximum, the density gradient and intensity of circulation likewise reach their maxima, and the steepest pressure gradient of the season is produced. When the temperature of the air over the land falls and the density gradient declines from its seasonal peak, the circulation that maintains the pressure gradient becomes weaker and air is thrust back from high to low pressure, that is from sea to land, so that the pressure gradient is reduced to accordance with the now weakened circulation. At each stage the pressure gradient is adjusted by the shifting of air from one side of the system to the other—from warm to cool side by deflection when the intensity of the circulation is increasing, from cool to warm side by unbalanced pressure when the intensity of the circulation is waning—to maintain a balance between pressure gradient and the push toward the right exerted by the moving air. In equilibrium the air flows parallel to the coast in the boundary zone between denser (cooler) maritime and less dense (warmer) continental air. On maps of mean pressure the gradient established and maintained by the flow of air parallel to the coast defines the North Pacific high on its eastern side.

Latitude in Relation to Winds and Pressure

Climatologic interpretation of the gradients seen on maps of mean pressure is subject to only one limitation: the gradients may be used in Shaw's sense as static indices of atmospheric currents only where the gradients are persistent through the period—month, season, or year—over which the means of pressure are taken and are not subject to frequent interruptions and reversals. For example, the eastward

and southward gradients of the North Pacific summer high may be confidently accepted as indices of steady streams of air but its northward gradient only with some reservation, since it is in part the mean of frequently interrupted gradients toward the centers of migrating cyclones. In latitudes up to 20° or 30° the gradients represented on maps of mean pressure for single months are persistent realities: they may safely be used as indices of large atmospheric currents.

Charts and tables designed as aids in the application of the gradient equation are easily accessible. In formulating the present discussion I have used the gradient-wind table in the Smithsonian Meteorological Tables.[4] It is arranged to give the velocity of the gradient wind when entered with latitude and pressure gradient as arguments. The table may equally well be used to obtain the latitude in which a wind of a given velocity produces a given pressure gradient. I have used it to obtain an answer to the following question: At what latitude will the winds that may be expected to arise from regional differences in air temperature produce a pressure gradient, with straight isobars, of 2.5 millibars per 5 degrees of latitude? On the daily weather maps of the United States this would be called a weak gradient—in latitude 40° it would be produced by a breeze of only 5 meters a second in the free air—and in high latitudes might possibly be the direct expression of a contrast in density between two adjacent air masses. But in low latitudes, where air masses of marked contrast in density do not come into juxtaposition, it could be produced only by a flow of air under the control of the earth's rotation. It is about the mean gradient over the oceans between the equator and latitude 20°.

The gradient-wind table is computed for frictionless conditions, which are approximated at some height above the surface of the earth, and for an air density of .001 gram per cubic centimeter. When using the table one must assume some elevation at which the wind is freed from the resistance offered by the ground and where therefore the adjustment of pressure gradient to wind velocity and direction may be freely attained. From aerologic observations made in the latitudes with which the present discussion is concerned[5] it appears that over land this elevation may be set approximately at 1500 meters. I have assumed further that at this level the velocity of the wind is twice its velocity at the ground. At 1500 meters in the tropics the density of the air averages about .001 gram per cubic centimeter,[6] the density for which the Smithsonian gradient-wind table is computed.

[4] Smithsonian Meteorological Tables, 5th revised edit., *Smithsonian Misc. Colls.*, Vol. 86, 1931, Table 41, pp. 72–73.

[5] K. Knoch and A. Lohr: Ergebnisse von Höhenwindmessungen auf dem Nordatlantischen Ozean und dem Karibischen Meer im April und Mai 1927, *Aus dem Archiv der Deutschen Seewarte*, Vol. 46, No. 2, 1928; P. M. Pummerer and R. O. Steiner: Höhenwindmessungen und andere Beobachtungen auf einer flugwissenschaftlichen Forschungsreise nach Rio de Janeiro und dem La Plata, *ibid.*, Vol. 49, No. 4, 1930; and other similar reports in the same series.

[6] V. Bjerknes, J. Bjerknes, H. Solberg, and T. Bergeron: Physikalische Hydrodynamik mit Anwendung auf die dynamische Meteorologie, Berlin, 1933, p. 644, Figs. 112 and 113. Curves in these figures show specific volume, the reciprocal of density.

Theoretical Limits of Equatorial Belt of Free Advection

The third column of Table I gives the latitudes in which the air movement represented by surface winds of the velocities listed in the first column produces a pressure gradient of 2.5 millibars per 5 degrees of latitude, under the assumptions named. This gradient is very nearly that represented in the Smithsonian table by a pressure difference of 1 millimeter of mercury in a distance of 300 kilometers; the data under that heading were therefore used without interpolation. Interpolation was necessary only for latitude. As the Smithsonian table gives no data for any latitude between 10° and 20°, it was augmented by the computation of gradient velocities with straight isobars for latitudes 11°, 13°, and 15°, in order to make the interpolation more accurate. The surface velocities used in Table I include the range of velocity represented by force 3, "gentle breeze," and force 4, "moderate breeze," of the Beaufort scale of wind force.

Table I—Latitudes at Which Given Wind Velocities Produce a Pressure Gradient of 2.5 mb. per 5° of Latitude*

Wind Velocity at the Surface (*Meters per second*)	Assumed Wind Velocity at Elevation 1500 Meters (*Meters per second*)	Latitude to Nearest 10′
3.5	7	25° 50′
4	8	22° 30′
5	10	17° 40′
6	12	14° 40′
7	14	12° 40′

*Straight isobars and air density of .001 gram per cubic centimeter assumed.

Inaccuracy in the estimate of increase in velocity from the ground upward to the height of 1500 meters does not affect the present argument: all that is necessary is that the free-air velocities listed in the second column of Table I be of the right order of magnitude. From the observations in the reports cited in footnote 5 it may be judged that velocities of 8 and 10 meters a second are representative of wind movement in the free air in the tropics. If the existence of a pressure gradient of the steepness used in computing the data in Table I is accepted as evidence that the earth's rotation has checked the free flow of air from a cooler to a warmer region, Table I states that such flow is checked at about latitudes 17° to 20°, when wind velocities of 8 to 10 meters a second in the free air obtain. In lower latitudes than these winds of the same velocities and lighter winds may blow freely from cooler to warmer areas without establishing sensible pressure gradients. The relation of wind to pressure gradient thus defines an equatorial belt within which regional advection may proceed freely,

in contrast with the rest of the earth's surface, where winds of the velocities that may freely exist in the equatorial belt establish pressure gradients that bar free ingress of maritime air to the interiors of continents. This equatorial belt will be called here "dynamically neutral"—neutral, that is to say, with respect to the deflective effect of the earth's rotation. According to Table I the width of the dynamically neutral belt varies with the intensity of circulation, expanding into higher latitudes when winds are weak and shrinking toward the equator when winds are strong.

Deduction from the gradient-wind equation cannot go much further, but the results of the deduction may be confronted with the distribution of precipitation over the lands in low latitudes, in order to test the validity of the assumptions made in assembling the data contained in Table I and to determine the extent to which the gradient-wind equation casts light on the regional distribution of precipitation. Two qualities of the distribution of continental precipitation in low latitudes are implied by the control of circulation by the earth's rotation. First, areas of precipitation during the rainy season should have distinct limits within the range of latitudes listed in Table I, the latitude of the boundary of a rainy area being in accordance with the intensity of the regional circulation on which it depends. Second, the isohyets defining the boundary should be clearly related to latitude, i.e. should run in an east-west direction.

Continental Precipitation Over Africa

The continent of Africa, astride the equator and extending into middle latitudes both north and south, provides the best empirical test of the theoretical deduction of the latitudes at which the earth's rotation becomes effective in limiting free advection of maritime air and hence precipitation in the interiors of continents. All rainfall maps of Africa for July show a sharp falling off in precipitation toward the north between latitudes 15° and 18° N. The isohyets run nearly east-west across the continent. To the north is an immense heated expanse of land that would receive moisture-bearing air from at least three directions if movement of air along density gradients were free. Such air is excluded by the rotation of the earth, which establishes a cyclonic circulation about the hot and dry northern part of the continent. On the south side of the cyclonic circulation is the steepest pressure gradient to be found in its latitude.[7] All the elements of the causal complex are accordant in magnitude: on the margin of the largest coherent continental area just beyond the dynamically neutral

[7] The pressure maps consulted are Charts 25 and 26 in L. A. Brooke Smith: Wireless and Weather—An Aid to Navigation, *M.O. 297*, Meteorological Office, Air Ministry, London, 1928. The precipitation maps of the whole of Africa used are those in Alexander Knox: The Climate of the Continent of Africa, Cambridge, 1911.

equatorial zone are found the steepest pressure gradient in latitudes 15° to 20° and the most abrupt decrease in precipitation on the poleward side of the equatorial rainy belt.

Summer precipitation in the southern lobe of the African continent does not show the effect of the earth's rotation so distinctly as does that in the broad northern part. Yet at the height of the summer of the southern hemisphere, in January and February, the isohyet of 8 inches on the map of mean monthly precipitation, which outlines the continental rainy area on its south side, crosses the continent nearly on the parallel of 17° S. Maps of rainfall during individual months of the rainy season[8] show the isohyets turning to an east-west direction and the amount of rainfall decreasing rapidly southward between the parallels of 16° and 20° S. Winter rainfall still farther south is conspicuously peripheral, in contrast with the summer rain north of 20° S., which is as conspicuously continental.

Distribution of Australian Rainfall

Australian rainfall is best represented on the maps of yearly and monthly precipitation issued every year by the Commonwealth Bureau of Meteorology. On the maps of the rainfall of individual years and of the months December to March, the months of heaviest rainfall in the tropical parts of Australia, the isohyets straighten at the south edge of the rainy belt approximately along parallels of latitude. As in the southern lobe of Africa, the rapid southward decrease in rainfall is in latitudes 17° to 20°. The courses of the isohyets on the maps of monthly and annual rainfall—obscured on small-scale published maps of means by the conviction of the map makers that rainfall should decrease concentrically inland from the sea—give to the dry interior of the continent a curiously rectangular shape in its northern part that is almost wholly independent of the continental outline. Due allowance being made for relief, precipitation decreases inland from the coasts south of about latitude 20°, as in South Africa. The rainy belt surrounding the dry interior is much wider in the north, where the ingress of maritime air is not impeded by the rotation of the earth, than in the south, in latitudes 30° to 35°, where winds of a given velocity produce pressure gradients about twice as steep as in latitude 18°.

Continental Precipitation Over South America

Rainfall data from the part of South America that is critical in the present connection—between latitudes 15° and 25° S. and longi-

[8] Published between January, 1924, and December, 1925, in *Monthly Weather Rept.*, Meteorological Office, Dept. of Irrigation, Union of South Africa. The maps for the months December, 1924, to February, 1925, are good examples.

tudes 50° and 63° W.—are particularly scanty. The isohyets drawn in this part of the continent on Knoch's map of January precipitation[9] are broken to confess the uncertainty of their courses. That there is, however, a noteworthy decrease in summer precipitation southward in the critical belt is indicated by the data assembled in Table II.

TABLE II—MEAN SUMMER PRECIPITATION AT STATIONS IN INTERIOR SOUTH AMERICA, LATITUDES 15° TO 25° S.

STATION	S. LATITUDE	W. LONGITUDE	MEAN PRECIPITATION, DEC.-JAN.-FEB. (*In millimeters*)
Cuyabá	15° 36′	56° 06′	673
S. Luiz de Caceres . . .	16° 04′	57° 41′	606
Corumbá	18° 59′	57° 42′	520
(Tres Lagôas)	(20° 47′)	(51° 42′)	(367)
Chaco Mission Station .	23° 23′	58° 25′	407
Villa Rica	25° 08′	58° 05′	402

All the stations listed are in the valley of the Paraguay except Tres Lagôas, which is borrowed from the drier Paraná Valley to fill the gap in latitude between Corumbá and Chaco Mission Station. Monthly maps of precipitation in Brazil show clearly the southward decrease.[10] The transition here is less abrupt than in the other continents: there is in South America no vast hot and dry interior having summer cyclonic circulation.

As if to compensate for the somewhat indefinitive testimony provided by the distribution of summer rain, the area of winter rain between the Paraguay River and the Atlantic coast is cut off sharply on the north between the parallels of 20° and 25° S., both on maps of July means and on those showing rainfall in individual calendar months from May to September. This is the only area to be cited in which the effect of the earth's rotation in setting an equatorward limit to an extratropical rainy area may be recognized. Rain-bringing maritime air is brought into the area of winter rains by migrating cyclones, and migrating cyclones—leaving out of consideration tropical hurricanes, which are maritime, not continental, phenomena —can exist only in latitudes in which winds produce pressure gradients under the control of the earth's rotation.

Apparently the south margin of the dynamically neutral zone lies slightly farther from the equator in South America than in Africa and

[9] K. Knoch: Klimakunde von Südamerika (Handbuch der Klimatologie, Vol. 2, Part G), Berlin, 1930, p. 70. The data in Table II are taken in part from Knoch, in part from H. H. Clayton, edit.: World Weather Records, *Smithsonian Misc. Colls.*, Vol. 79, 1927.

[10] Maps in the annual *Boletim Meteorologico*, issued by the Directoria de Meteorologia, Ministerio da Agricultura, Industria e Commercio, Rio de Janeiro.

Australia. The Andean barrier insulates the continent from the general circulation of the atmosphere on one entire side, so that seasonal cyclonic and anticyclonic circulations, such as determine the distribution of pressure over Africa and Australia at the extreme seasons, are not so well developed as in the other two continents. The weaker circulation produces pressure gradients, the evidence that free continental advection is checked, in latitudes higher than in Africa and Australia.

Bearing on Hypothesis of "Lag" of Tropical Rainy Belt

The theoretical and empirical evidence cited in the foregoing has an immediate bearing on the hoary climatologic dogma of a "lag" behind the zenithal sun in the meridional swing of the tropical rainy belt. According to this dogma, some time after the arrival of the zenithal sun in a given latitude is required to induce the supposed "heat convection" to which the summer rains are traditionally ascribed. Hence, the argument runs, the amplitude of the swing of the rainy belt always remains less than the width of the belt between the solar tropics. It has been known since at least Humboldt's time, however, that in the areas having tropical rainy and dry seasons the period of highest temperature does not coincide with the rainy season and that higher temperatures are observed beyond the pendulating belt of rains than in it. From the viewpoint of the relation between wind and pressure gradient on a rotating earth it is possible to interpret the pendulation of the rainy belt without dodging the implications of seasonal march and areal distribution of temperature in low latitudes of the summer hemisphere. It is clear, that is to say, that the poleward limit of an area of zenithal rain must be determined, not by the solar tropic, but by the parallel of latitude at which the rotation of the earth transforms free advective circulation into cyclonic circulation about an area of high temperature. This parallel may, with weak winds, be located in the vicinity of the tropic; but the testimony of the distribution of seasonal rainfall indicates that it lies oftener in a lower latitude. The failure of zenithal rain to reach the tropical circles is thus not the result of lost motion in a loose-jointed atmospheric mechanism: rather it is the unerring manifestation of the control exercised by the earth's rotation over the circulation of the atmosphere.

BATHYMETRIC STUDIES OF THE LAKE MICHIGAN BASIN

O. F. Evans
University of Oklahoma

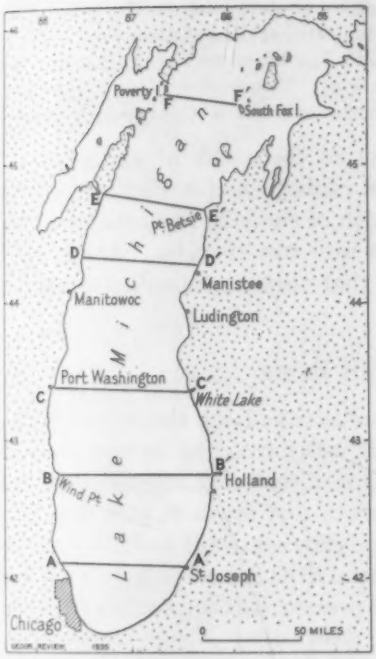

FIG. 1—Lake Michigan: key to cross sections shown in Figure 2. Scale: 1:6,500,000.

The application of the fathometer to deep-sea sounding has made it possible to map the bottom of a water body with an accuracy and speed comparable to that of a topographic survey. During the summer of 1930 the United States Lake Survey resurveyed the deeper parts of Lake Michigan by this method. The soundings were made at intervals of about three-quarters of a mile in east-west lines six miles apart. Except for the 10 and 20-fathom lines, which are from the Lake Survey charts numbers 7 and 70, the accompanying cross sections were taken from a bathymetric map made from the original blueprints of the deep-sea soundings.

Section A-A′ is from St. Joseph to a point a few miles north of Chicago. In this section there is a suggestion of a terrace at a depth of 20 fathoms. The bottom of the south end of the lake is probably nearly in equilibrium with respect to the work of the waves and currents. The average current along both shores is to the south, and at the time of northerly winds, which are strong in autumn and winter, there must be a very strong north-moving current on the bottom. This is probably enough to move the sandy material out to the greatest depth that occurs in this part of the lake. Along the axis of the greatest depth the bottom slopes gradually northward to a depth of 80 fathoms in 60 miles.

In section B-B′, Holland to Wind Point, the uniformity of bottom is similar to that just described. The gradual deepening from south to north continues and reaches 90 fathoms. There is some indication of a shelf at 20 fathoms on the west side but none on the east.

In section C-C′, White Lake to Port Washington, there is no evidence of terracing. Almost equidistant from each shore is an elevation that rises to within 22 fathoms of the surface and is roughly elliptical in shape, for there is also a slope to the north and south at a somewhat lesser rate. Between the 60 and 70-fathom lines west of the elevation the slope is about 180 feet to the mile, which is steep for this part of the lake bottom.

Section D-D′ is about four miles north of Manistee. From section C-C′ to D-D′ there is a rapid deepening, and a double trough occurs. The elevation between the

two is an oval ridge that slopes 10 miles to the northeast and the same distance to the southwest to a depth of 120 fathoms. In the general area of this section the bottom is more irregular than farther south.

At section E-E′ the deepest part of the lake is nearly in the middle. The eastern trough shallows, and the ridge separating it from the deep to the west rises to a depth of 60 fathoms. Twenty miles south of the deepest part of this section is the greatest depth of the lake, 154 fathoms. One and a quarter miles from Point Betsie the 20-fathom line is reached, and there is a suggestion of steepening to the west. Five miles out from the west shore a terrace is also indicated at the 20-fathom line.

Section F-F′ is from the north end of South Fox Island to Poverty Island. The bottom here continues irregular and is shallowing. Twenty-five miles to the north there is a depth of only 40 fathoms. From the east the section deepens rapidly.

The lake basin is rather uniform to the south of section C-C′. To the north of that line it deepens rapidly, and a number of oval elevations about a quarter of the width of the lake from the east side have a tendency to divide the basin into two troughs. The general shape and position of these suggest that they are possibly erosional, rather than depositional, features.

Origin of the Basin

It is impossible to draw any conclusions about the origin of the lake basin from its shape alone. If it was formed by stream erosion, the more favored theory, then the shape of the basin suggests that the tributaries perhaps came from the north and south to join the main stream somewhere near Ludington and flow eastward toward Saginaw Bay. The rock surface under the glacial drift is known to be very low here but is so deeply covered that at present it is impossible to prove the presence or absence of a preglacial river valley. On the other hand, it is possible that certain relatively rapid differences in elevation of the bottom of the lake, such as occur off the shore from Ludington to the Fox Islands, may be due to faulting. But definite evidence on whether the basin has a structural or erosional origin seems to await a better knowledge of the rock surface beneath the drift of the region.

The Subaqueous Terrace

According to present theories of wave work there should be a subaqueous terrace along the shores of Lake Michigan extending out to a depth of 150 to 200 feet if the lake level has been stationary long enough for such a shelf to develop. No published observations of the height and length of the waves of Lake Michigan are available, but it is probable that the average storm waves are 15 to 18 feet high and 150 to 200 feet long. Waves 300 feet long and 25 feet high are mentioned by Gaillard[1] as occurring on Lake Superior, but these are the extremest storm waves. The waves on Lake Michigan are not so large.

[1] David Du Bose Gaillard: Wave Action in Relation to Engineering Structures, *Professional Papers, Corps of Engineers, U. S. Army, No. 31 (War Dept. Doc. No. 225)*, 1904.

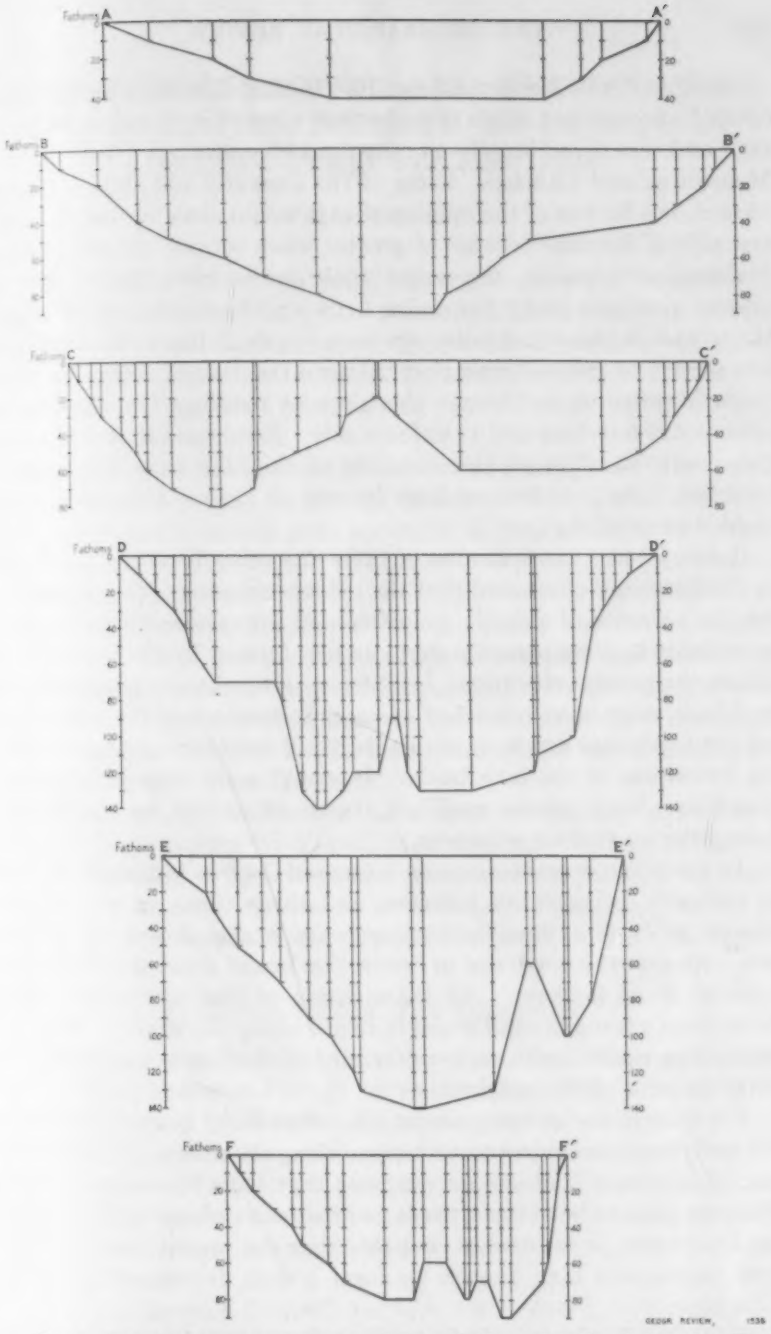

FIG. 2—Bathymetric cross sections through Lake Michigan along lines indicated on Figure 1. Horizontal scale: 1 : 1,350,000; vertical exaggeration: 176. Based on data from U. S. Lake Survey.

Andrews[2] and Fenneman[3] both state that a terrace exists in the Great Lakes out to a depth of 60 feet. Andrews' work was done before 1870 and was based largely on nine lines of soundings taken between Manitowoc and Chicago. Some of the lines did not show a definite terrace, but he was of the opinion that it would show up better on the east side of the lake because of greater wave action. In order to test Andrews' conclusions, the writer took points from the 10 and 20-fathom contours every five miles between Manitowoc and Chicago. If a terrace is present, the distance from the shore line to the 10-fathom line should be greater than that between the 10 and 20-fathom lines. From Manitowoc to Chicago this gave 15 readings favorable to the existence of a terrace and 17 unfavorable. Readings taken in the same way every 10 miles on the east side of the lake from Frankfort to Michigan City gave five readings for and 18 against the presence of a 10-fathom shelf.

Johnson[4] also made studies of these and other localities mentioned by Andrews and concluded that the evidence was not enough to establish the presence of a shelf. Johnson is of the opinion that there may be terraces in some places at 20 to 40 feet formed by the waves of the lake at the present elevation. Indications of terraces at greater depths, he thinks, may be remnants of terraces formed when the lake waters were at a different height or remnants of old river terraces made during the formation of the lake basin. It would seem that river terraces would have been greatly modified, if not obliterated, by glacial work during the several ice advances.

In the given cross sections an increased slope is found six times at 20 fathoms, twice at 30 fathoms, and three times at 40 fathoms, though in two of these last an increase is also shown at 10 fathoms. Also, at the north end of South Fox Island a definite shelf seems to show at 10 fathoms. An examination of the bathymetric chart shows even greater irregularities in depth along the shores. This certainly does not indicate such uniformity of shelf as is known to exist along the edge of the continents.

We cannot say at the present time that there is any continuous and well developed subaqueous terrace along the shores of Lake Michigan. Since there is abundant evidence that Lake Michigan has been above its present level three times and below it at least twice since the last ice retreat, it is entirely probable that the present level has not been maintained long enough to form a well developed terrace at wave base.

[2] Edmund Andrews: The North American Lakes Considered as Chronometers of Post-Glacial Time, *Trans. Chicago Acad. of Sci.*, Vol. 2, 1870, pp. 1–23; reference on pp. 4–7.

[3] N. M. Fenneman: Development of the Profile of Equilibrium of the Subaqueous Shore Terrace. *Journ. of Geol.*, Vol. 10, 1902, pp. 1–32; reference on p. 31.

[4] Douglas Johnson: The New England-Acadian Shoreline, New York and London, 1925, pp. 405–416.

INCOME DISTRIBUTION AND THE RELATION OF POPULATION DENSITY TO INCOME IN THE UNITED STATES, 1929

Allen Belden

RELIABLE figures denoting aggregate personal incomes by state units may be given geographical expression in several ways. Such figures, moreover, provide a basis for measuring the degree of adjustment between population density and income; i.e. of ascertaining what states have few or many inhabitants in proportion to income.

Aggregate personal incomes in the United States have been rationally estimated for 1929 by Leven, Moulton, and Warburton. The results are listed by states in an appendix to their recent work "America's Capacity to Consume."[1] These estimates are based on the best available data, supplied mainly by the "Fifteenth Census of the United States," the Bureau of Internal Revenue, and the Department of Agriculture. They are computed totals of personal incomes derived from all types of productive activities engaged in by the entire population. Hence they are equivalent to the total economic production of each state, or, in other words, to the sum of the values of all goods produced and all services rendered.

Average per capita incomes have been adequately presented in tabular and map form by Leven, Moulton, and Warburton and will not be treated here. The purpose of this paper is to use their estimates of aggregate incomes in order to show the distribution of income per square mile and the relation of population density to that distribution.

Personal Income Per Square Mile

Figure 1a shows the distribution of personal income per square mile in the United States in 1929 in terms of comparative indices. It has been constructed by dividing aggregate personal incomes by areas and assigning indices proportionate to income per square mile. The average personal income per square mile in the United States was $28,645. This figure was accepted as normal and arbitrarily given the index of 100. State averages ranged widely above and below the national average.

Figure 1a reveals that the parts of the country most productive of income per square mile were those where manufacturing and commerce were of chief importance and population was densest. Southern New England, New York, and New Jersey had indices above 1000,

[1] By Maurice Leven, H. G. Moulton, and Clark Warburton (Publs. Brookings Instn., Inst. of Economics Ser. No. 56), Washington, 1934, p. 174.

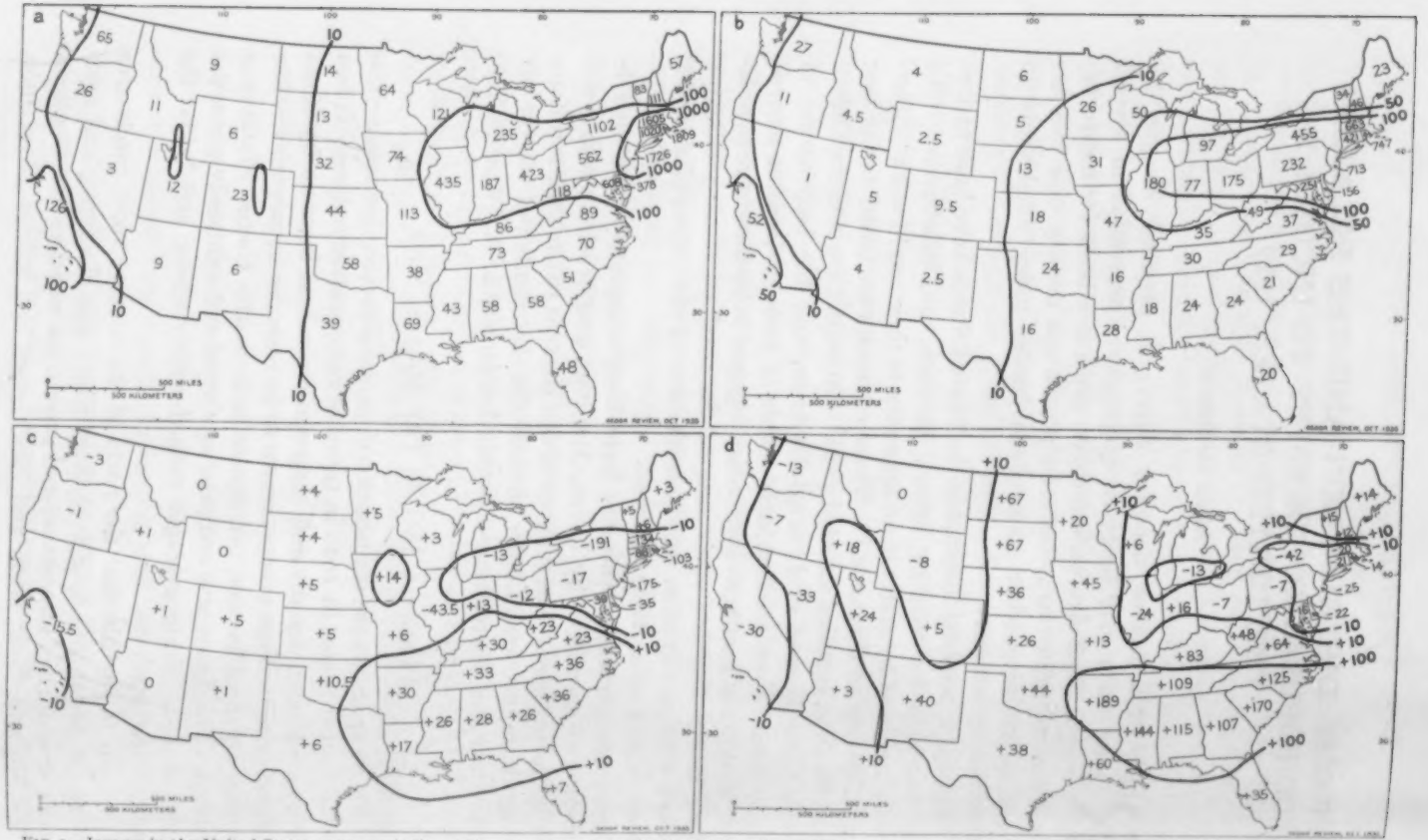

FIG. 1—Income in the United States, 1929: a, indices of income per square mile; b, density of population per square mile adjusted to income indices; c, excess and shortage of population in relation to income; d, percentage of excess and shortage of population in relation to income. Scale 1 : 50,000,000.

and a belt of indices above 100 extended from the Atlantic seaboard between Maine and Virginia westward into Wisconsin and Missouri. On the Pacific coast only California had an index of more than 100.

Elsewhere the values of income per square mile were below the national average. In the arid and mountainous western parts of the country, where resources were meager and the population engaged in developing them was sparse, indices were particularly low. In other areas, where the main dependence was on agriculture and extractive industries rather than on commerce and manufacturing but where the population was fairly dense, economic production per square mile was only moderately low. The whole southeastern quarter of the country, the wheat belts, northern New England, and Washington and Oregon had indices between 10 and 100.[2]

Relation of Population Density to Income

Indices of income per square mile provide a basis for measuring the degree of adjustment between population density and economic production, or the extent to which states have many or few inhabitants in proportion to income. Were the distribution of population in the United States adjusted perfectly to the distribution of income per square mile—i.e. if all individual incomes were the same—then each state would support an average population density proportionate to its index of income. An adjusted distribution of population for 1929 has been computed by multiplying the average population density of the United States by the income index of each state divided by 100. For example, since the average population density of the United States in 1929 was 41.3 persons per square mile, Oklahoma, whose income index was 58, received an adjusted density of .58 times 41.3, or 23.9 persons per square mile. The results of this procedure are shown on Figure 1b. Then in order to determine which states were densely or sparsely populated in proportion to income it was necessary only to compare the figures thus derived with the actual population densi-

[2] Isopleths have been drawn empirically on the maps accompanying this paper. State units are too large to admit of accurate detail. The writer has experimented with criteria that are available by counties in an effort to establish substitute measures of economic production. It has been found that when states are used as units there is a good correlation between indices based on the income estimates of Leven, Moulton, and Warburton and combined indices based on retail sales less food sales, property-tax revenues, and total bank deposits. The average percentage deviation of the substitute indices from income indices was 12 per cent. The coefficient of correlation between the two was .99. This proves nothing conclusively about counties. However, it is probable, in view of the close correlation obtained between the two sets of indices when states were used as units, that the three substitute criteria are at least fairly reliable measures of the relative economic production of counties. Combined indices of retail sales less food sales, property-tax revenues, and total bank deposits have been computed by county units for Oklahoma in the same way that indices of income have been computed for states. It was found by this procedure that, although Oklahoma as a whole had an average income index of only 58, Kay, Ottawa, Oklahoma, Pottawatomie, Seminole, Okmulgee, Tulsa, Muskogee, and Washington counties had indices above the national average. Other counties were proportionately low in rank. Explanation of the high ranking of individual counties undoubtedly lies in the location of producing oil fields and large commercial cities.

Fig. 1.—Income in the United States, 1929: a, indices of income per square mile; b, density of population per square mile adjusted to income indices; c, excess and shortage of population in relation to income; d, percentage of excess and shortage of population in relation to income. Scale 1 : 30,000,000.

ties. Figure 1c is the result of such a comparison. It shows to what extent actual densities departed from computed densities in terms of population per square mile.

Figure 1c reveals that, for the most part, the areas with high indices of income per square mile were sparsely populated in proportion to income. Evidently in 1929 people who engaged in manufacturing and commerce received larger average incomes than those who were dependent on agriculture. Practically all the states where agriculture was the main source of income, and particularly the older and more densely populated of these states, had many inhabitants in proportion to income. Iowa and the southeastern states had excess populations of more than ten persons per square mile. Undoubtedly agriculture was in a weakened financial condition before the industrial collapse of 1929. The map seems to indicate that manufacturing centers were the last strongholds of the prosperity of the last decade. Certainly there was much to justify the movement of population from farms of the southeast to cities of the northeast. Comparable maps for 1935 would doubtless reveal somewhat different distributions, but unfortunately 1929 is the latest year for which reliable income estimates are available.[3]

Figure 1d shows departures of actual from computed population densities in terms of percentages of computed densities. In Arkansas, Mississippi, Alabama, Georgia, Tennessee, and the Carolinas critical social and economic conditions are reflected by the fact that actual population densities were more than double the computed densities. Most of the predominantly agricultural states had excess populations of more than 10 per cent. Percentages of population shortage were nowhere so large as the more extreme percentages of excess population. In 1929 New York, with 42 per cent, had the highest percentage of population shortage: this shows that the average per capita income was higher there than in any other state.

Explanations of the conditions revealed by the accompanying maps are not within the scope of this paper. The object has been, rather, to call attention to the value of income data to geographers. It should also be observed that income is not a complete measure of economic standards of living and that the analysis if carried further should include some consideration of regional differences in average costs of living.

[3] In 1929, although Oklahoma as a whole had a population excess of 10.5 persons per square mile, three counties had population shortages in terms of national standards; namely Tulsa, Oklahoma, and Seminole. Other counties had proportionate excesses (see footnote 2).

GEOGRAPHICAL RECORD

NORTH AMERICA

The Snow Survey and Summer Precipitation. On the assumption that the precipitation of any region is largely the reprecipitation of local evaporation rather than new moisture brought in from the ocean Professor O. W. Monson has attempted to correlate snow-survey records with records of summer precipitation (The Snow Survey as an Index to Summer Precipitation, *Monthly Weather Rev.*, Vol. 62, 1934, pp. 322–330). The test was made in Montana, fortunately situated on the eastern slope of the Continental Divide far from original water supplies in the Pacific Ocean, the Great Lakes, or the Gulf of Mexico. The summer precipitation at the lower

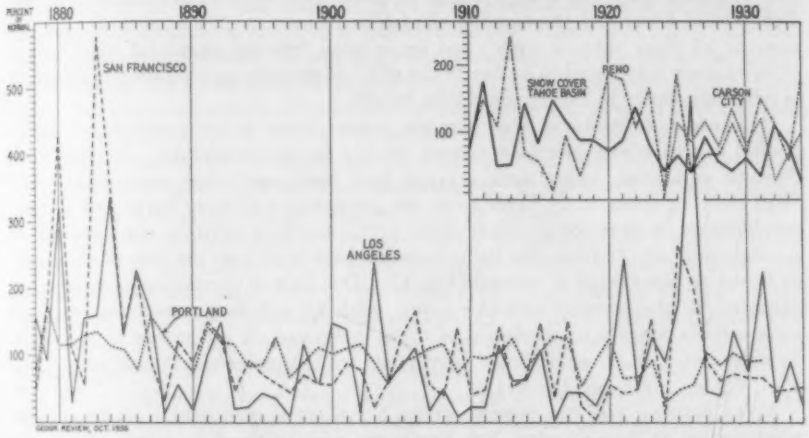

FIG. 1—The main graph shows April–July precipitation at three stations along the Pacific coast of the United States, expressed as per cent of normal. (Normals: San Francisco, 2.61 in.; Los Angeles, 1.58 in.; Portland, 7.19 in.) The smaller graph shows April–July precipitation at Carson City and Reno as compared with snow cover in the Tahoe basin (per cent of normal). The per cent of snow cover indicated is a weighted mean in which the western stations of the basin are given two times the weight of the eastern stations; the figures are also weighted according to zones.

levels may be conceded to be due to local evaporation and recondensation. At least, the precipitation in the lowlands in summer (April-August) is from two to three times as heavy as in winter (November-March). Furthermore, the precipitation at the higher elevations in winter must necessarily exceed that at the lower elevations in summer. For even at the moderate elevation of Hebgan Dam (6550 feet) the winter precipitation of 8.2 inches is practically equal to the summer precipitation at the lower stations of Billings, Havre, Helena, and Miles City.

The principle that Monson seeks to establish is that the heavier the snow cover the heavier are the summer rains to leeward, or at least that the snow cover and the subsequent summer precipitation are both on the same side of normal.

Snow surveys carried out in the St. Mary River drainage basin on May 1 each year (1922–1933) afforded an attractive opportunity of comparing the snow cover with the summer precipitation at Havre and Geraldine. Says Professor Monson: "The similarity of the curves is remarkable. It may be noted that the slope of the estimated curves, that is, up or down, showing increase or decrease as compared with the previous year, is correct 11 out of 12 years for Geraldine and 10 out of 12 years for Havre, and that a forecast of 'above normal' or 'below normal' would have been correct in 10 out of the 12 years for each place."

"But this correlation," he admits, "does not necessarily prove a direct causal

relationship between the snow cover on the St. Mary River watershed and the summer rainfall at Havre and Geraldine. Perhaps they are associated as kindred effects of a third factor, or perhaps they show similar variations because affected by other similar though distinct underlying influences. This, however, does not detract from the practical value of the apparent relationship."

Since other snow-survey systems were lacking in Montana, a comparison was next made between summer runoff in other basins and the summer precipitation in adjacent lowlands. Both runoff and precipitation are expressed in percentages of normal. The plan seemed feasible, for close percentage relationships had been found elsewhere between snow cover (as surveyed) and subsequent stream flow.

However, a consistent relationship could not be discovered between all of the precipitation stations and the adjacent runoff, nor was the relationship continuous. For example, there was a high degree of correlation between the runoff from the Beaverhead River and the summer rainfall at Miles City "from 1918 to 1928 and none at all from 1912 to 1918" and again none "during 1929 and 1930." Part of this failure may possibly be due to the effect of summer precipitation itself, which is relatively heavy in this region during runoff.

It seems more probable that summer precipitation is the complex product of several causes whose interplay cannot readily be predetermined. In the Sierra Nevada watershed, where snow surveys have been conducted continuously since 1910, only 14 times in 25 years have the percentages of snow cover and summer precipitation in their lee at either Reno or Carson City been on the same side of normal, and only 11 times has the correlation been within 40 per cent of each other as based on percentage of normal (Fig. 1). This lack of correlation is further emphasized by the presence of Lake Tahoe, with an unfailing water surface of 300 square miles directly to windward of these towns and at a distance of only 15 to 25 miles (see J. E. Church: Snow Surveying: Its Principles and Possibilities, *Geogr. Rev.*, Vol. 23, 1933, pp. 529–563).

As an extreme test the present writer has made a comparison of the summer precipitation at Los Angeles, San Francisco, and Portland in terms of seasonal percentages from 1878. Since these cities lie immediately leeward of the Pacific Ocean, whose water supply must always be considered normal, their percentages of summer rainfall should also always be normal and similar. Yet their individual variations are great, and rarely do more than two of the three agree even approximately. The almost consistent lack of correlation between the two elements of source and subsequent precipitation is evident from Figure 1.

Thus even here, where the winds blow consistently from the water source, less correlation can be found than in the examples given above.

The difference in precipitation between the Continental Divide and the Sierra Nevada or Pacific coast is one of intensity rather than character. In the winter the snow supply seems to come in both places from the Pacific. In the summer the precipitation in all three regions is mainly convective but relatively far less copious on the coast than east of the Continental Divide. Therefore the evidence in one region should apply to the others.

However we interpret Monson's data, we must at least agree heartily with his conclusion that "precipitation and run-off records are extremely valuable if kept consistently and continuously and that more are needed. Run-off records should be kept on all streams where they emerge from the mountains and at other key points along their courses. Meteorological data taken at high altitudes and so distributed as to be representative of large areas are also needed." J. E. CHURCH

Fairs, Old and New. One might say that the fair as a trading institution attained its apogee in the fairs at Puerto Bello on the Caribbean coast of the Isthmus of Panama. From the end of the sixteenth to the mid-eighteenth century these served

as the vehicle of trade between two worlds (A. C. Loosley: The Puerto Bello Fairs, *Hispanic Amer. Hist. Rev.*, Vol. 13, 1933, pp. 314–335). More or less localized, this primitive type of fair still retains importance in Latin America. An example from Guatemala has recently been described by Webster McBryde in "Sololá: A Guatemalan Town and Cakchiquel Market-Center" (*Middle American Research Series, No. 3 of Publ. No. 5*, Tulane Univ., 1933). Sololá is a highland town of 2600 population 80 miles west of Guatemala City. In addition to the weekly Friday market Sololá holds two annual fairs, one in the week preceding Holy Week, the other in mid-August, celebrating the Feast of the Assumption. At a typical Friday market 1100 vendors were counted from 18 neighboring towns as well as Sololá. At the fairs the market is more than doubled in size, and the goods offered for sale are far more varied and brought from farther afield. Livestock, for instance, is usually offered only at the fairs, and dried fish from Mexico and honey from Antigua. The influence of modern trade, however, is making itself felt. There is no barter, nor does one any more see the "hand" of salt as a form of currency; bulk goods are no longer sold by volume but by weight. While a large part of the commodities of trade in the region thus passes directly from producer to consumer, a special class of middlemen exists in the itinerant pack traders who go from town to town and region to region. In this latter connection reference may be made to "The Inter-Community Trade of the Indians of the Utatlan Basin in Guatemala" by Rollin S. Atwood (see abstract in *Annals Assn. of Amer. Geogrs.*, Vol. 25, 1935, pp. 32–33).

While the modern agricultural fair may hardly be described as a "direct lineal descendant" of the trading fair, it has many characteristics in common with that primitive institution, especially on the social side. The avowed purpose of the agricultural fair is the improvement of agriculture. This specialized form of fair and its evolution are the subject of an interesting study by Wayne Caldwell Neely (The Agricultural Fair, *Columbia Univ. Studies in the Hist. of Amer. Agric., II*, New York, 1935). Professor Neely finds the origin of the agricultural fair in the agrarian revolution of the eighteenth century in England, where agricultural leaders sought to disseminate the knowledge of new crops and new methods by the organization of agricultural societies that eventually fathered the agricultural fair. In America, where a like development took place, the agricultural fair found a "golden age" in the expansion of agriculture westward in the mid years of the nineteenth century. The early fairs were as general in character as the rural society of the times was homogeneous and unspecialized. The rise of the automobile is one of the determining conditions of its current status. The extent to which it has become specialized and differentiated is illustrated, to take one feature only, in the emergence of a class of professional fair organizers. And yet in pursuing the evolutionary course of the agricultural fair "it is easy to see how it partakes of the nature of the exposition with its ostentatious display, how it resembles in some respects the commercial sample fair, how it still retains a touch of the primitive harvest festival, how amusement and recreation attractions combine survivals of medieval days with the latest devices of thrill and spectacle."

The Fishery Industry of California. In 1910 less than 50 million pounds of fish were landed at Californian harbors; in 1929 (the peak year), 857 million pounds. This spectacular rise was due to the introduction of canning: whereas the greater part of the 1910 catch was marketed fresh, 92 per cent of the 1929 catch was cannery fish. The growth of the canning industry with its evolution of vessels, gear, and methods is described by Clifford M. Zierer in an article in the March, 1935, number of the *Scottish Geographical Magazine*. The place of Los Angeles in this development is the theme of a paper by Professor Zierer in the October, 1934, number of *Economic Geography*. (In the July, 1935, number of the same journal Professor J. Q. Adams discusses the Pacific-coast halibut fishery, whose centers lie between Cape Blanco,

Oregon, and the Aleutian Islands. On certain larger aspects of the fishery industries see also the article by Professor Hjort in the present number of the *Review*.)

Of special interest is the rapid extension of the tuna fishing grounds. Packing of albacore, a species of tuna, was begun in 1903 during a temporary drop in the sardine fishery. By 1911 the albacore fishery, based on rich harvests gathered in the waters about Catalina Island, had firmly established canneries at Los Angeles and San Diego. Markets expanded. Attention was directed to other species of tuna. By 1918 the waters off southern California were unable to supply enough of any species of tuna to meet the demand. The fishery turned to the waters off Lower California. Turtle Bay, 500 miles south of San Diego, became an important center. In 1927 Mexican waters supplied more than three times as much as the home waters. Not only the fishing grounds were extended but, following fish migrations, the season also. Little competition was offered by Mexican boats, but the duties and fees imposed by the Mexican government were a source of much trouble. The chief difficulty arose from the fact that, although the fish were caught beyond the 3-mile limit, live bait had to be sought in territorial waters. The outcome was not unlike that in Antarctic whaling, in which floating factories made the industry independent of land stations. A type of refrigerated boat was developed that could remain at sea a month or more and keep the bait alive for the duration of the voyage. Not to lose all revenue, the Mexican government responded by permits to obtain fresh bait at fixed charges a trip.

Some of the large new tuna fishing cruisers have gone as far south as Costa Rica, Panama, and Peru and as far west as Hawaii and even beyond in search of tuna. In 1932 one boat visited Christmas, Palmyra, Washington, and Fanning islands. Though the longer trips have not usually been profitable, they have proved the wide spread of tuna grounds. In 1933 several of the tuna cruisers were based at Balboa, Panama.

A late development in the tuna fishery is competition from Japan in the home market. For a number of years frozen albacore has been imported from Japan: in 1932 the amount had diminished, whereas that of the canned product had greatly increased. The sardine industry also has suffered serious competition from Japan and Russia, but in the export market, the chief outlet of the sardine industry. Partly for this reason, partly on account of the general depression in trade and its consequences, exports of canned sardines from the United States dropped from 124 million pounds in 1929 to 27 million pounds in 1932.

Competition with the Far East is also reflected in the canned-salmon industry of the Pacific coast (compare figures cited by Otis W. Freeman: Salmon Industry of the Pacific Coast, *Econ. Geogr.*, Vol. 11, 1935, pp. 109–129).

SOUTH AMERICA

Laguna de Mar Chiquita. The discovery of archeological remains on the banks of the Mar Chiquita in a region found by the early Spanish conquerors to be almost unpopulated presents certain interesting features (Joaquín Frenguelli and Francisco de Aparicio: Excursión a la laguna de Mar Chiquita (provincia de Córdoba), *Publs. Museo Antropológico y Etnográfico de la Facultad de Filosofía y Letras*, Ser. A, Vol. 2, Buenos Aires, 1932, pp. 121–147).

Mar Chiquita is a shallow, brackish lake without outlet, some seventy kilometers in length and about twenty kilometers in width (compare "Wandering Lakes of Dry Regions: The Mar Chiquita," *Geogr. Rev.*, Vol. 23, 1933, p. 670). Its high salt content has been derived from large volumes of sweet water that accumulated within a much larger basin during humid climatic phases of the past and have evaporated under the present subarid climate. Salt content has varied from 6 per cent in 1890 to 36 per cent in 1912 and 26 per cent in 1930. This susceptibility to

minor fluctuations in climate during the recent past makes it evident how much greater the variations were under the climatic changes of the Pleistocene and the early Recent.

Terraces along the shores tell the history of recurring changes of water level as Mar Chiquita varied successively between sweet-water lake and salt-water swamp. The lowest of these terraces is characterized by wind-blown sands. Where streams enter the lake, there are deposits pertaining to the estuaries and deltas that succeeded one another, the former containing diatoms of salt water, the latter of sweet and of salt water.

One of the deltas is represented today as the Isla Chica, at the old mouth of the Río Primero. Here it was that Frenguelli and De Aparicio found the traces of early inhabitants that they describe—fragments of old pottery, a buried skeleton, and remains of primitive fireplaces that had been dug by hand to a diameter of about half a meter and a depth of 15 to 20 centimeters and lined with baked earth. Apparently they date back to a time that, although comparatively recent, found Mar Chiquita's water level much lower and Isla Chica a long peninsula connected with the mainland. But at such time the waters of Mar Chiquita were probably even more brackish than they are today—so how account for these manifestations of human life? The authors conclude that they represent temporary seats of habitation, probably for pottery making from clay of the older lacustrine deposits.

W. E. RUDOLPH

Geographical Activity in São Paulo. In 1934 the University of São Paulo, Brazil, established a chair in geography, to which M. Pierre Deffontaines was called from Lille. Such progress was made that at the end of the year the chair was transformed into an Institute of Geography, with Professor Deffontaines as director (*La Géographie*, Vol. 63, 1935, pp. 236–237). Among his other activities Professor Deffontaines is evidently finding time for research: he contributes a suggestive paper "Recherches sur les types de peuplement dans l'Etat de Saint-Paul (Brésil)" to the April, 1935, number of the *Bulletin de l'Association de Géographes Français*. He has also organized an Association of Brazilian Geographers, which meets fortnightly and publishes a quarterly magazine, *Geografia*. The first number of *Geografia* contains articles dealing with São Paulo—the soils, the distribution of rural property, the early history, citriculture, karst phenomena, and the distribution of Japanese immigration (120,000 Japanese immigrants to São Paulo in ten years).

EUROPE

The Origin of the Rural Landscapes of France. Among the generalizations not infrequently repeated in geographical textbooks is one to the effect that rural habitations in Europe are clustered in villages where permeable rocks yield a water supply only here and there and are scattered widely over the countryside where impermeable rocks furnish an abundant supply nearly everywhere. Field and map studies, however, have shown that there are many areas underlain by permeable rocks where the habitations are scattered and that the contrary is true of many areas of impermeable rocks. In a recent study based largely on the investigation of old maps and other archival materials Roger Dion makes it clear that concentration and dispersal of rural habitations in France are not determined primarily by the water supply but depend rather on what he calls the "structure des terroirs." This may be rendered "pattern of agricultural land utilization" (Roger Dion: Essai sur la formation du paysage rural français, Tours, 1934; see also note on recent studies in the geography of rural settlements, *Geogr. Rev.*, Vol. 24, 1934, pp. 502–504).

Dion maintains that the outstanding regional variations in the rural landscape are

due to differences in these patterns and that the patterns as they present themselves today had their origin in agricultural practices of the medieval period and earlier. There are two fundamentally divergent types of pattern: a northern type, which prevails over the northern part of the Paris basin and is characterized by open fields with compact clumps of woodland, and a southern type, found in the southern Paris basin and throughout most of the rest of France and distinguished by the limited extent of open fields and the scattering of trees among the cultivated grounds. The border line between the main areas over which these two types prevail shows a more or less close adjustment, not to underlying rock structure, but to the distribution of soils, which depends rather less on local geological than on broader climatic circumstances. The limit of the area of open fields corresponds fairly closely with the limit of the rich loam (*limon*) that is widespread in northeastern France. Except along this border, there is but little correlation with any circumstances of the natural environment. Dion attributes the essential difference between the two types of pattern and the major control of their distribution to historical and social rather than geographical factors, though he recognizes that geographical factors have played a part in fixing the detailed trace of the line that separates them. The northern type suggests similar patterns in northern and eastern Europe and is to be regarded as a heritage from the pastoral economy of northern folk. The system of open fields represented in its beginnings the northerners' solution of the problem of feeding stock on a collective, coöperative basis. The southern type, on the other hand, had its origins in the rural economy of Rome and Italy, in which stock raising was of minor importance and individual initiative in arboriculture and the cultivation of field crops was stressed. For the many anomalies within the areas where each type prevails Dion finds historical explanations. In concluding he states that his main purpose is to "warn against the risks of error to which one is exposed in substituting for true geography a superficial geology which, although without doubt capable of explaining certain local details, gives little idea of larger relationships." The monograph is an excellent demonstration of the importance of applying historical as well as strictly geographical methods to the interpretation of geographical landscapes.

Regional Studies of Yugoslavia. "La Metohija" by Milisav Lutovac (*Trav. publiés par l'Institut d'Études Slaves*, Vol. 14, 1935) deals with an area some 65 kilometers long by 30 to 35 kilometers wide drained by the White Drin. It is a natural unit, the fertile plain of a tectonic depression in the wild mountain country on the Serbo-Albanian borders. In the Middle Ages Metoya was the economic and cultural center of the later Serbian kingdom. Prizren was the chosen royal residence, Peć the seat of the patriarchship of the Serbian church. The greater part of the rich lands of the plain were in the hands of the monasteries, whence the name Metoya. Under Turkish rule Metoya sank to become "the most anarchistic and least safe part of the Balkans." Many of the inhabitants fled, and Albanian mountaineers descended to take their place. With liberation from the Turkish yoke in 1912 Metoya reëmbarked on a period of prosperity. Lutovac paints a glowing picture of the "colonization" process now under way through private and governmental initiative. Government is planting settlers on forested land susceptible of cultivation on clearing; roads are being built, irrigation promoted (the heart of the basin has an average rainfall of only about 20 inches), and schools and hospitals established. The colonists are drawn chiefly from Montenegro, but they come also from other adjacent provinces and from northern Albania. New villages are springing up all over the country, and new forms of agricultural economy are being introduced—the maize-hog combination for instance, little known here formerly. A promising resource lies in the tourist industry. Metoya offers historic sites and shrines—to which, indeed, pilgrimages have long been made—encompassed by some of the most striking scenery of the Balkans. The exploitation of the hot springs is also beginning.

Professor B. Ž. Milojević's regional studies are well known (compare "The Kingdom of the Serbs, Croats, and Slovenes: Administrative Divisions in Relation to Natural Regions," *Geogr. Rev.*, Vol. 15, 1925, pp. 70–83). His monograph on the Dinaric coasts and islands was published by the Royal Serbian Academy in 1933. The work is in three parts. The first and second parts deal in detail with selected areas; the third is a systematic treatise of the region as a whole. This last part has been translated into French and published as "Littoral et îles dinariques dans le royaume de Yougoslavie" (*Mémoires de la Société de Géographie de Beograd*, Vol. 2, 1933). It includes a map on the scale of 1:1,500,000, an ambitious attempt at a geographical synthesis of natural and human features, and many photographic illustrations. Reference may also be made to the maps and photographs of the atlas of the Geographical Society of Belgrade in course of publication under Professor Milojević's direction. Recent installments present photographs of the bay of Kotor (No. 11, 1934) and the great lakes of southern Serbia (No. 12, 1934).

The Solar Climate of the French Riviera. The popularity of the French Riviera as a resort may be ascribed largely to the sunshine, which attracts tourists and invalids during the winter. The Riviera enjoys a solar climate of a type not duplicated elsewhere within the same distance of the dour and cloudy skies of northern Europe. On the basis of observations made since 1928 the elements of this solar climate are analyzed in a recent monograph by Ladislas Gorczyński (Climat solaire de Nice et de la Côte d'Azur, *Mémoire IV de l'Assn. des Naturalistes de Nice et des Alpes-Maritimes*, Nice, 1934). In this study the observations are presented, and in addition a full discussion is given of the instruments and methods employed and the theoretical principles upon which they are based (see also H. H. Kimball: Solar Radiation and Its Rôle, *Bull. Natl. Research Council No. 79*, 1931, pp. 35–66).

Latitude, atmospheric conditions, and topography determine the solar climate of a place. In the absence of direct instrumental measures of the intensity of insolation, it is possible to arrive at reasonable approximations of its value by studying these three factors alone. From records of the duration of sunlight at Nice, the mean annual insolation for the period 1931–1933 is estimated at 146.3 kilogram calories per square centimeter of horizontal surface; the corresponding figure based on records of cloudiness is 153.3. These estimates are strikingly confirmed by the solarigraph, an instrument which records the intensity of radiation received directly from the sun itself and indirectly from the entire celestial vault. The figure obtained by the solarigraph is 148.3. Elsewhere in this number of the *Review* (pp. 601–617) an interesting example is given of an investigation of insolation in relation to land utilization in the Alps. This study shows that valuable conclusions may be reached regarding insolation even where no instrumental measurements of meteorological and actinometric conditions are available.

Gorczyński furnishes some figures that permit comparisons of the solar climate of Nice with that of other regions. In this connection see also Kimball (*op. cit.*, pp. 48–49), where maps of the world will be found showing total solar radiation over the oceans at the solstices with cloudless sky and at the solstices and equinoxes with average cloudiness. The mean duration of sunlight at Nice is 7.2 hours a day as compared with only 4.8 hours at Paris. During November, December, and January Nice gets two or three times as much sunlight as Paris. The ratio of actual sunshine to the maximum possible for the latitude is 60 per cent at Nice, 37 per cent at Paris, 33 per cent in Holland, and less than 30 per cent in Scotland. During the winter the ratio at Nice is in the neighborhood of 60 per cent, whereas in the non-Mediterranean parts of France and over the greater part of northern and central Europe it scarcely exceeds 20 per cent. "To find ratios of insolation during the winter that are like those of the Côte d'Azur, it is necessary to take certain stations in the south of Europe, particularly on the southern coasts of Spain . . . " These figures are merely for

duration of sunlight. When insolation is measured in terms of energy, we have seen that Nice receives annually 148 kilogram calories per square centimeter. Comparable figures for other points are: Paris 98, Helsinki 75, New York 95, Washington 122, Chicago 90 (see also H. H. Kimball: Measurements of Solar Radiation Intensity and Determinations of Its Depletion by the Atmosphere, *Monthly Weather Rev.*, Vol. 58, 1930, pp. 43–52, Table 5). In North America "solar conditions analogous to those of the Côte d'Azur must be sought in certain favored spots on the Pacific coast (southern California, particularly in the Mexican part or toward the desert of Arizona)."

Lakes of the French Pyrenees. The posthumous publication of studies of glaciation and lakes of the French Pyrenees by the Abbé Gaurier (Les lacs des Pyrénées françaises, Toulouse and Paris, 1934) presents the basic results of a lifelong investigation. Gaurier drew attention to the great profusion of lakes in the region and has left a series of detailed observations of great value. He became firmly convinced that the ability of glaciers to erode is inconsequential as compared with that of running water.

According to Gaurier the present topography records a period of later-Tertiary stream erosion in which the present valley pattern was established. During the Pleistocene the valleys were occupied by extensive glaciers, and some scouring was accomplished by the ice, but the main work was done by melt water. In recent times, with vastly diminished glaciers, running water has continued to play a more important part in the sculpture of the land. In formulating his opinions concerning ice action from observations of existing glaciers he noted, for example, that the exposed slopes are crumbling rapidly, whereas the rock bed of the glaciers, where uncovered, is fresh and polished, with no trace of demolition. The ice and snow "*protègent le sol* au lieu de le dégrader." In penetrating subglacial tunnels, he found the outstanding work to be that of melt water. It is not apparent from the text, however, why these and observations of similar character preclude an active and extensive eroding power for glaciers, but they do emphasize the rapidity of stream erosion and weathering processes in comparison with ice erosion and the facility with which glaciated surfaces can be destroyed.

Gaurier advanced the belief that the majority of the many lakes that he studied and mapped for the first time lie within small tectonic basins, tiny synclines transmitted to the surface by deeper orogenic movements. The geologic relationship of these basins varies widely: for example, the shores of Lac de Campo-Plano are granitic on three sides but schistose to the south; those of Lac d'Artouste are granitic save for the southwest bay, which lies within a limy band. It is suggested that this contact of rocks of unequal resistance may be one of the chief reasons for the lake basins, but its relation to the original surface folds is not made clear. Text photographs to illustrate the intense folding to which the region has been subjected (p. 53) show extensive erosion. Where lakes lie entirely within granite, Gaurier sought an explanation in original irregularities in the upper part of the granitic magma. In the text the implication is given that these lakes belong to the tectonic group, but the presence of this deep-seated rock at the surface implies much erosion. If there be good reason for placing lake basins developed entirely within granite in the tectonic group, it is not clearly stated.

As agents in the formation of the lake basins both water and ice are considered, but both are excluded because of a conviction that neither could excavate such basins. In only one case in the French Pyrenees, mentioned but not studied by Gaurier, is there a glacier in contact with a lake. This, Lac Tourrat, has recently been studied and surveyed (Chabanat, Fourcaud, and De Traversay: Reliques glaciaires aux Pyrénées, *Rev. du Club Alpin Français*, Vol. 61, 1935, pp. 123–134). The location of the lake at the snout of the glacier strongly suggests a relation between ice erosion,

rock basin, and lake. If Gaurier had allowed a somewhat greater erosive power for ice, he might have considered glacial excavation of the rock basins as a valuable working hypothesis in explaining their origin.

Forest Conservation Under the Venetian Republic. Forest conservation is nothing new in Europe. As early as the fifteenth century the Venetian government, like the British government at a later period (see *Geogr. Rev.*, Vol. 18, 1928, pp. 341–342), was vitally interested in preserving timber for the use of its navy. "Like any maritime power Venice was dependent upon access to the terrestrial products from which the ships were made. . . . Only the efficient exploitation of the natural resources of the mainland possessions acquired in those Italian wars for which the policy of the Republic has been so frequently criticized enabled the Venetian Arsenal to supply the war fleets which did battle with the Infidel." These words are quoted from a chapter on the timber supplies in a recent scholarly volume by Dr. F. C. Lane on "Venetian Ships and Shipbuilders of the Renaissance" (The Johns Hopkins Press, Baltimore, 1934).

Fir, larch, and oak were required. Most of the fir and larch timbers were obtained from the Rhaetian and Carnic Alps, whence some of them were floated down the streams. Oak, for which there was an even greater demand, was obtained partly from the neighboring mainland and partly from the peninsula of Istria. "A definite policy designed specifically to conserve and increase the oak groves was first formulated between 1470 and 1492." Subsequently the Arsenal reserved certain woods and trees for its own use. Cadastral surveys of the oaks were made periodically after 1568. An elaborate system of administration and inspection was organized. The regulations were often hard to enforce, partly on account of the depredations of timber thieves and livestock and partly as a result of the disinclination of villagers to coöperate with the officials. "Amidst the record of all these difficulties, however, can be seen the growth of an enlightened conception of forest management, a realization that a forest should not be exploited like a mine but that timber was a crop to be cultivated under a definite plan." As early as the middle of the fifteenth century "deforestation was recognized as a danger to the lagoons since it increased the amount of silt brought down by the rivers. To prevent this filling up of the lagoons, the Council of Ten ordered the replanting of all cut-over woods at the edges of streams or salt water."

Dr. Lane believes that the decline in Venetian commerce in the sixteenth and seventeenth centuries is to be ascribed in part at least to the exhaustion of the timber supply despite the steps taken to conserve it. "The need for ships was enormously increased in the sixteenth century by the development of the transoceanic trades. . . . The carrying trade of both the Indies and even that of the Mediterranean then passed in very large measure to the countries of northwest Europe able to draw upon the still unexhausted forests of that region" (F. C. Lane: Venetian Shipping During the Commercial Revolution, *Amer. Hist. Rev.*, Vol. 38, 1932–1933, pp. 219–239, reference on p. 237).

PHYSICAL GEOGRAPHY

Dust. Dust is a word of broad connotation: poet and preacher understand it so; the scientist is more limited and specialized. We are indebted to Dr. S. Cyril Blacktin for the stimulus he gives to the scientific imagination in "Dust," a view of man living on and in dust (London, 1934). For the enveloping dust he coins the word *staubosphere*. Every aspect is touched on—the nature and origin of dusts, ancient and modern; dust in meteorology, geology, botany, industry and technology, and medicine. His instances range all the way from the deposition of cosmic dust to the use of dust in crime detection; from the dust of Babylon to the International

Conference on Silicosis at Johannesburg in 1930. It goes without saying that such enthusiasm and prodigious industry scarcely permit of considered statement, and some of Dr. Blacktin's arguments are fallible (see review in the *Quart. Journ. Royal Meteorol. Soc.*, Vol. 61, 1935, pp. 222–223); but his work has a unique value.

Dr. Blacktin's bibliography of 545 items in itself suggests the scope and diversity of dust studies. The theme may be illustrated by four topics lately come to our attention. The dust of Peiping is famous, but it has received little scientific attention. In "The Dust of Peking" by Yung-chi Ma (*Bull. Geol. Soc. of China*, Vol. 13, 1934, pp. 627–646) an attempt to throw light on its composition, texture, and origin is made from analysis of measured dustfalls. In the realm of theory is Mr. C. S. Durst's paper "Dust in the Atmosphere" (*Quart. Journ. Royal Meteorol. Soc.*, Vol. 61, 1935, pp. 81–89). He speculates on the movement of dust in the atmosphere as affected by its reaction to radiation and remarks that "it is conceivable that the dust ejected by Krakatoa, for instance, may never have returned to the earth, but may have diffused over the whole of the upper layers of the atmosphere."

The airplane is enabling us to secure data on the distribution of micro-organisms by air currents. Experiments conducted at the Massachusetts Institute of Technology on meteorological flights in 1932 showed that bacteria, molds, and pollen might be expected up to a height of 20,000 feet at least (B. E. Proctor: The Microbiology of the Upper Air, I, *Proc. Amer. Acad. of Arts and Sci.*, Vol. 69, 1934, pp. 315–340). It is "easy to understand how plant diseases may be transmitted through the travels of spores." On his North Atlantic flight in 1933 Colonel Lindbergh made collections of micro-organisms of the air at 26 points between Maine and Denmark, including several over the inland ice of Greenland. "In these collections are found spores of fungi, pollen grains and fragments of fungous hyphae. . . . In addition were found unicellular algae, fragments of filamentous algae and insect wings, diatoms, objects tentatively identified as sponge spicules, volcanic ash and glass, and other microscopic débris of the air" (F. C. Meier: Collecting Micro-Organisms from the Arctic Atmosphere; With Field Notes and Material by Charles A. Lindbergh, *Scientific Monthly*, Vol. 40, 1935, pp. 5–20).

To come back to earth. "Highway contractors appreciate accurate temperatures near the surface when laying concrete and more especially certain forms of asphalt which cannot be laid when the temperature is less than 45°," says Mr. Foster V. Jones apropos of difficulties of temperature forecasting in Nashville on account of smoky air (Effects of Local Smoke on the Climate of Nashville, Tenn., *Monthly Weather Rev.*, Vol. 63, 1935, pp. 55–57). A difference of 11 degrees of temperature has been noted between the forecasting station in the city and the suburbs. "Few cities in the United States have a greater smoke nuisance to contend with during the winter months than Nashville." Several papers in recent numbers of the *Journal of the Tennessee Academy of Science* testify to local interest in Nashville's smoke problem.

The Cold Pole of the Earth. Since the seventies of the last century textbooks on geography have placed the cold pole of the earth at Verkhoyansk, on the Yana River in northeastern Siberia. After his expedition of 1926 Professor Obruchev (see the present number of the *Review*, p. 629) expressed the opinion that still lower winter temperatures might prevail at the settlement of Oimekon (see above, Fig. 1, p. 626) on the Indigirka, some 650 kilometers southeast of Verkhoyansk. Observations carried out during the years 1929–1934 at a meteorological station established at Oimekon by the Soviet Academy of Sciences have confirmed this view (for comments on the records of 1929–1930 see *Meteorol. Zeitschr.*, Vol. 48, 1931, pp. 359–360; *Petermanns Mitt.*, Vol. 78, 1932, pp. 23–24; *Meteorol. Mag.*, Vol. 68, 1933–1934, pp. 280–283).

The mean monthly temperatures for the summer months of 1930, 1931, 1932, and

1933 were approximately the same at Oimekon and at Verkhoyansk. During the rest of the year Oimekon was somewhat colder. In 1931 a mean January temperature of −55.7 C. (−68.3 F.) was experienced there, and an absolute minimum for the four years of −67.7 C. (−89.9 F.) was recorded on February 6, 1933.

In eastern Siberia decrease in temperature accompanies increase in altitude during the summer only. In winter the reverse is the case owing to the downward flow of masses of excessively cold air. Air drainage of this type proceeds unhindered because

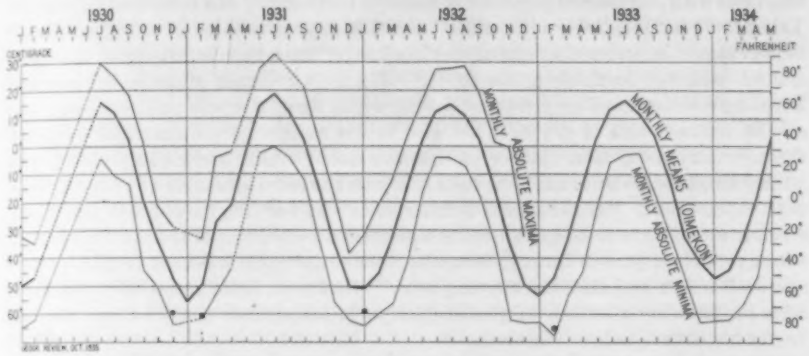

FIG. 1—Monthly temperatures at Oimekon, 1930–1934. The stars indicate annual absolute minimum temperatures at Verkhoyansk.

of the almost perfect calm that prevails over northeastern Asia. Observations of 1917–1918 at the station "Semenovski Rudnik" high up (1020 meters) in the Verkhoyansk Mountains showed a mean January temperature in 1918 of −28.0, whereas the following means for the month were recorded in the neighboring lowlands: Verkhoyansk (150 meters), −48.9; Yakutsk (108 meters), −40.0; Viliusk (120 meters), −34.2.

Verkhoyansk and Oimekon both lie in basins surrounded by almost unbroken mountain ranges. The accumulation of cold air in these basins accounts for the extraordinarily low temperatures. Oimekon itself is fairly high (754 meters), but the surveys of Obruchev, Salishchev, and B. Sonov have shown that the station is situated in a valley ten or twelve kilometers wide eroded below the general level (1000 meters) of the Oimekon plateau, which in turn is encircled by mountains rising to altitudes of 1500 to 2000 meters.

K. A. SALISHCHEV

Pleistocene Eustatic Shift of Sea Level in Cuba. In 1931 Robert W. Sayles reported evidence of Pleistocene fluctuation of sea level in Bermuda (Bermuda During the Ice Age, *Proc. Amer. Acad. of Arts and Sci.*, Vol. 66, No. 11, 1931, pp. 381–468). One of the most important lines of attack, apart from direct evidence of change in position of water level such as is recorded by marine caves, rests on the presence of five fossil soils interbedded with calcareous eolian sand. Sayles suggests as a "feasible explanation" that these deposits were associated with Pleistocene glaciation and deglaciation: during a period of ice advance, when water was withdrawn from the oceans, the broad platform upon which Bermuda rests was exposed to the action of winds, and dunes were formed; during retreat, when water was again returned to the oceans, soils were leached from the wind-blown material. (For discussion of Bryan and Cady's reconstruction of Pleistocene climate based on this study see C. E. P. Brooks: The Pleistocene Climate of Bermuda, *Geogr. Rev.*, Vol. 25, 1935, pp. 340–342.)

Along the southern shore of eastern Cuba, where active faulting and raising of

block mountains were taking place during the Pleistocene and successive marine terraces were being cut into the shore-facing fault fronts, Taber has recently suggested that glacial eustatic shift of sea level accompanied the uplift of the coast (Stephen Taber: Sierra Maestra of Cuba, Part of the Northern Rim of the Bartlett Trough, *Bull. Geol. Soc. of America*, Vol. 45, 1934, pp. 567–619). Eustatic change of sea level is not easily demonstrable along a coast where faulting has been recently active, and the correlation of fragmentary terraces along a differentially uplifted coast line with interpreted positions of sea level is obviously of a controversial nature. Taber finds it "seemingly impossible" to make any correlation of terraces. Available evidence indicates that recent displacements "have been intermittent and have shifted back and forth along the coast." He finds evidence of an emergence followed by a widespread submergence during which limestone was deposited not only on the seaward side of the hills but also in the stream gorges that had been cut through the coastal hills. His belief that the recent submergence was probably due largely to eustatic rise in sea level rests solely on the reasonableness and simplicity of that explanation. "If the recent submergence was not due to eustatic rise in sea level, it would have to be explained by widespread subsidence of the land in a region where mountain growth through irregular differential uplift has been in active progress both before and since the submergence." However, there seems to be but little hope for evolving a history of glacial changes in sea level in eastern Cuba such as Sayles has attempted for Bermuda.

Tides in Wells. That fresh-water wells located near the coast or near a tidal river are subject to the tide has been noted for centuries. The amplitude of the tidal movement in such wells is generally much less than that along the neighboring coast. With respect to phase, the relation varies from almost complete synchronism to complete opposition. The phenomenon obviously is not a simple one.

In a recent dissertation entitled "De Invloed van de Getijbeweging van Zeeën en Getijrivieren op de Stijghoogte van Grondwater" (Delft, 1934) J. H. Steggewentz studies the phenomenon systematically. After a brief review of the literature of the subject since ancient times he develops mathematically the formulae for the transmission of the tidal movement along a coast into the water-bearing strata in the neighboring coastal region. These formulae are rather involved, since they must take into consideration the geological make-up of the water-bearing strata. The results, however, agree very well with the observations. As a rule, the retardation in time of high or low water in a well, as compared with the tide outside, increases with increasing distance from the coast. This, therefore, explains the occurrence of opposite phases of the tide in a well and along the outside coast.

As to the cause of the tidal movement in wells, it is obvious that the direct effect of the tide-producing forces of sun and moon on the water of a well is so minute as to be out of the question. Of the two hypotheses that have been advanced in recent years, one is based on the plastic deformation of the strata overlying the water-bearing area with which the well is connected, due to the varying load of tidal water. The other is based on the direct effect of the varying pressures imposed on the ground water by the rise and fall of the tide. Steggewentz' formulae are based on the latter hypothesis.

A valuable feature of the publication is a section listing the scattered literature on the subject. However, Schureman's paper on "Tides in Wells" (*Geogr. Rev.*, Vol. 16, 1926, pp. 479–483), which presents the results of one of the more recent systematic investigations in the United States, is omitted. H. A. MARMER

HISTORY OF GEOGRAPHY

Two Eighteenth-Century Maps of the Philippine Islands. Father Miguel Selga, S.J., director of the Manila Observatory, has made a valuable contribution to the

history both of cartography and of Philippine researches in a recent monograph on two maps of the archipelago published in 1734 and 1744 (Los mapas de Filipinas por el P. Pedro Murillo Velarde, S.J., *Publs. Manila Observatory*, Vol. 2, No. 4, 1934). The compiler of these maps, Father Murillo (1696–1753), was a Jesuit of notable scholarly attainments who had been sent from Spain to Manila in 1723. Besides the maps, he was author of a comprehensive "Geographia historica" in ten volumes (Madrid, 1752) and of several historical and religious works.

Murillo's map of 1734 (ca. 1 : 1,650,000; Selga's reproduction, ca. 1 : 2,500,000) was prepared by order of the king of Spain. The title, "Carta Hydrographica y Chorographica," shows that it was essentially a mariner's chart, and this is borne out by the many reefs indicated and by the abundance of names of capes and points along the coasts. On this map 188 islands are named and many others shown without names. Murillo believed that an earlier estimate of 1200 islands in the archipelago was an exaggeration, though modern investigations have disclosed that there are about 7000. The map also gives many details of the interior, including 613 towns and villages, most of which Father Selga identifies. The map of 1744 ("Mapa de las Yslas Philipinas") is on a smaller scale (ca. 1 : 3,200,000; Selga's reproduction, 1 : 4,500,000) and is much less detailed. Both maps reveal a remarkably accurate concept of the coastal outlines and general relationships of the islands. They were compiled partly on the basis of earlier works but largely from personal observations and conversations with other authorities. The engraving was done by Nicolás de la Cruz Bagay, a competent Filipino craftsman, and the printing was carried out at a press maintained by the Jesuits, one of three printing establishments in the Manila of that time. It is striking that the facilities for such excellent technical work then existed in this remote colony. Besides full details regarding the maps, Father Selga gives a brief account of Murillo's life, a chapter on the engraver, and a bibliography of Murillo's works. The maps remained authoritative until as late as 1800 and were often copied (see John Bach: Philippine Maps from the Time of Magellan, *Military Engineer*, Vol. 22, 1930, pp. 351–359).

GEOGRAPHICAL NEWS

Division of Geographic Names. The Secretary of the Interior has appointed as Executive Secretary of the Division of Geographic Names Dr. George Curtis Martin, of Corvallis, Oregon. Dr. Martin was for twenty years a geologist of the U. S. Geological Survey. Repeated journeys through all but one of the 48 states of the United States as well as in Alaska, Canada, Mexico, and Central America have given him acquaintance with the problems of place names.

The Division of Geographic Names, successor to the U. S. Geographic Board, was set up by Secretary Ickes under the authority of President Roosevelt's Executive Order of April 17, 1934 (see "Sixth Report of the United States Geographic Board, 1890 to 1932," *Geogr. Rev.*, Vol. 25, 1935, pp. 150–151).

OBITUARY

Leon Dominian. Mr. Leon Dominian, first secretary of the United States legation at Montevideo, died in that city on July 25, aged 55 years. Mr. Dominian was on the staff of the American Geographical Society during the period 1912–1917. He then entered the services of the Department of State, where he was engaged in the study of boundary problems, including an assignment to the American Commission to Negotiate Peace in Paris, 1919. Consular service in Rome and Stuttgart was followed by the recent appointment to Montevideo.

Mr. Dominian had traveled widely and had special linguistic qualifications and knowledge of the Near East—he was born in Constantinople and was resident there

for many years. He was a member of the Association of American Geographers. He contributed many articles to the *Bulletin of the American Geographical Society* and other periodicals, and he was the author of the timely book, "The Frontiers of Language and Nationality in Europe" (*Amer. Geogr. Soc. Special Publ.* [*No. 3*], 1917).

Curtis Fletcher Marbut. On August 25 a report from Harbin, Manchuria, brought the sad news of the death from pneumonia of Dr. Curtis F. Marbut at the age of 72. America's leading authority on soils, Dr. Marbut was on his way from Oxford, England, where he had attended the meetings of the Third International Congress of Soil Science, to Peiping, to undertake a study of Chinese soils at the request of the Chinese government. From 1910 until his death he was in charge of the soil surveys of the United States—since 1924 as Chief of the Division of Soil Surveys of the U. S. Department of Agriculture. Under his direction the soils of about half of the area of the country were mapped. An inventory of the soil resources of the United States by Dr. Marbut will soon be published by the Department of Agriculture as Part 3 of its "Atlas of American Agriculture."

In presenting the Cullum gold medal of the American Geographical Society to Dr. Marbut in 1930 the late President John Greenough of the Society said: "He has plowed a deep furrow in the virgin field of soil geography. By his skillful application of the philosophy and principles of modern science to the classification and mapping of soils he has given new direction to man's conquest of nature—the better utilization of that precious heritage, the soil, 'foothold of all things.'" Dr. Marbut's interests were broad and his temperament philosophical. A master in the technical details of soil science, he also saw with the eyes of a statesman the wider economic and social bearings of the soil and the study of soils. It was largely through his influence that the fundamental work of the Russian pedologists became known in America (he translated into English K. D. Glinka's "The Great Soil Groups of the World and Their Development," Ann Arbor, Mich., 1927). His scholarly presidential address before the Association of American Geographers in 1924 dealt with "The Rise, Decline, and Revival of Malthusianism in Relation to Geography and Character of Soils" (*Annals Assn. of Amer. Geogrs.*, Vol. 15, 1925, pp. 1–29). To the *Geographical Review* he contributed several papers of distinction, notably on geography at the First International Congress of Soil Science (1927)—a congress that he helped materially to organize—on the soils of the Amazon basin in relation to agricultural possibilities (1926), and two important comparative studies of Russia and the United States from the points of view of soils and agriculture (1931). In coöperation with Dr. H. L. Shantz he contributed a volume "The Vegetation and Soils of Africa" to the American Geographical Society's *Research Series* (1923).

GEOGRAPHICAL REVIEWS

Ethiopian Borderlands

L. M. Nesbitt. **Hell-Hole of Creation: The Exploration of Abyssinian Danakil.** xi, 382, and viii pp.; map, ills., index. Alfred A. Knopf, New York, 1935. $3.75. 9 x 6 inches.

Wilfred Thesiger. **The Awash River and the Aussa Sultanate.** Maps, ills. *Geogr. Journ.*, Vol. 85. 1935. pp. 1–23.

E. J. Bartleet. **In the Land of Sheba.** xiii and 181 pp.; maps, ills., index. Cornish Brothers Ltd., Birmingham, 1934. 7s. 6d. 8½ x 6 inches.

The Emperor Menelik once described his country as having survived as "an uplifted island of Christians in an ocean of pagans for more than fourteen centuries" (quoted in "The Last Partition of Africa?" *Round Table*, No. 99. June, 1935. pp. 507–523; reference on p. 511). The survival of independent Ethiopia up to the present is in fact largely due to that pagan sea; but its protective role may all too easily be reversed, as the Walwal incident suggests. Ethiopia, the fortress state, is a "perplexing problem for the three Powers whose possessions march with her own enormous lowland moat; this is the desert of scrub and thorn that stretches from the Indian Ocean and the Red Sea to the rocky bastions and Alpine ranges of Abyssinia proper." The "moat" functions to perfection in Danakil, in the northeast. Hot, desertic, its surface in places 300 to 400 feet below sea level, its occupants wild savages, this is a country "whence no explorer had yet returned alive." Mr. L. M. Nesbitt, an English mining engineer, found in Danakil a challenge and a conquest. With two companions, Italians resident in Ethiopia, and a caravan of 15 natives, 25 camels, and 4 mules, but without permission from the Ethiopian government, he set off from the Awash station on the Addis Ababa-Jibuti railroad in March, 1928. His plan was to cross the Danakil country on its long axis, i.e. from north to south. The first part of the journey followed as close to the Awash River as possible, but a considerable detour had to be made to the plateau for refitting the caravan before reaching Aussa. Aussa may be said to divide northern from southern Danakil. Nominally under the suzerainty of Ethiopia, it is virtually independent. Here the Awash bifurcates, and on its deltaic muds millet is grown—the only place of cultivation in Danakil, hence its widespread repute. The Sultan, who rules Aussa with a firm hand, does not welcome foreigners. Nesbitt was the first European to be entrusted with his "Silver Baton" safe-conduct. Nesbitt, however, only skirted the western border of Aussa; his route lay north. This second stage, through sand deserts and across barren lava fields with water holes at times a four or six days' journey apart, proved extremely trying. Nesbitt reached the Italian frontier on June 26, whence he proceeded by mining tram line to Mersa Fatima. A part of Mr. Nesbitt's story was told in the *Geographical Journal*, and his map on the scale of 1 : 750,000 first appeared therein (Vol. 76, 1930, pp. 298–315, 391–414, and 545–557). Reference should also be made to the panoramic sketches accompanying the *Journal's* account.

In 1933–1934 another English traveler, Wilfred Thesiger, made a successful journey in southern Danakil. Thesiger was able to fill in a part of the middle course of the Awash not seen by Nesbitt and to explore its lower course in a series of swamps and lakes, terminating in the great sodium lake Abhebad, which apparently has no outlet. From this point Thesiger struck out north to the salt basin of Lake Assal and east to Tajura, whence he took a dhow to Jibuti.

If topography and climate present serious difficulties to the traveler in Danakil, so do the inhabitants. Fierce and bloodthirsty, they are "more like wild animals

than men," says Nesbitt. The tribes are engaged in perpetual warfare, and a man's standing in his tribe depends on the number of his human victims. "An elaborate system of decorations displays his prowess to his contemporaries, and a line of stones upright before his memorial hands down his fame to posterity," says Thesiger. The surprisingly elaborate tombs of the chiefs are described and depicted by both writers. Both also have observations to make on the salt trade, the chief business of the coasts they touched. Nesbitt estimated the salt plain crossed at the northern end of his journey to cover 2000 square miles; but in spite of this great extent the bordering tribes are perpetually fighting for the right of exploitation. The salt is cut in bars 12 by 1½ inches in size and shipped by camel caravan to the plateau, where they serve as commodity and currency. Thesiger notes a similar trade from the Assal salt plain. Major R. E. Cheesman, commenting on the use of the salt in western Ethiopia, says that in some country districts it is the only accepted form of currency; people will take it when they refuse the Maria Theresa silver dollar, "remarking that they cannot eat dollars." The price on the plateau varies with the price of silver.

Mr. Nesbitt entered Ethiopia from the west by the Blue Nile, and as a preliminary to the narrative of his journey he has some interesting chapters on the approach to Addis Ababa and his residence therein. The experiences of another English mining engineer in the capital and on a concession in the platiniferous region of the west are recounted in Captain Bartleet's "In the Land of Sheba."

How Man Changes the Earth's Surface

Edwin Fels. **Der Mensch als Gestalter der Erde: Ein Beitrag zur allgemeinen Wirtschafts- und Verkehrsgeographie.** 206 pp.; bibliogr. Bibliographisches Institut, Leipzig, 1935. RM. 5.80. 10 x 6½ inches.

The title of this volume expresses concretely the essence of its contents. Although Professor Fels has not presented anything particularly new, he has rendered a service in focusing attention upon a phase of geography now being developed among proponents of "social" geography and among those who style themselves chorographers. He offers in systematic arrangement a summary of the numerous ways in which man acts as a "molder" or modifier of the earth.

An attempt to accomplish a similar objective through photography was beautifully set forth in 1930 by Creutzburg in his "Bilderatlas" (reviewed in *Geogr. Rev.*, Vol. 21, 1931, pp. 525–526), to which Fels gives due credit. However, some activities of man are not readily treated in this manner, and hence the author's belief that such a volume as his is desirable. He expresses the hope that it may constitute one "stone" in the building of a geography of the economic or cultural landscape, a phase of geography which to him is but in its incipient stages.

Man's effect upon climate, meaning the use of greenhouses, irrigation, protection against frost, hail, and other weather elements; the influence of mining upon the landscape through the creation of great holes, culm piles, and cave-ins; changes in waterways, such as river canalization, flood control, and the creation of lakes by dams and canal construction—these are some of the subjects treated. Further discussion refers to changes in the landscape resulting from deforestation, afforestation, agriculture, wild-animal-life depletion, redistribution of animals, overland transportation, and changing forms of cities.

While these numerous modifications are in part consequences of the development of the sciences, yet in turn many of our sciences have been aided by changes wrought by man. Geology has been aided by exposures in railroad cuts, tunnels, wells, canal and harbor construction; oceanography was stimulated by the laying of undersea cables; and aviation has fostered advances in meteorology. Another interesting point is Dr. Fels's comment upon human population of the ocean. He shows that

between 1925 and 1928 the average number of persons living on the North Atlantic Ocean, including passengers and crews, was 40,000 per day. This number excludes the personnel on freighters, many of whom have permanent quarters on these boats.

A bibliography of 117 titles presents an excellent cross section of recent publications (for the most part in German) bearing especially on the field of man as a modifier of the earth.

EUGENE VAN CLEEF

GEOGRAPHY AND ETHNOGRAPHY

C. DARYLL FORDE. **Habitat, Economy, and Society: A Geographical Introduction to Ethnology.** xiv and 500 pp.; maps, diagrs., ills., bibliogr., index. Methuen & Co. Ltd., London, 1934. 15s. 9 x 6 inches.

Those students of primitive life who are chiefly interested in its economic and other objective aspects tend to arrange their data in a geographical framework to the end that it may be difficult to say whether a particular research falls under geography or ethnography. The book under review is in this class and by its title warns the reader that it may be considered a contribution to geography. Yet the contents may well serve as an introduction to primitive culture and thus avoid a common weakness in anthropological books devoted to the description of selected types of primitive life but failing to organize the data presented around a well defined point of view.

The stated objective is to sketch the basic economic patterns for specific selected groups of people so chosen as to meet the requisites of sampling. Naturally this is not random sampling, and little fault can be found with the choices. Not only are the economic patterns of these types well sketched, but good notes on the physical environment are given. The author's assumption regarding the concomitance of the two is that the human group adjusts itself by making such concessions to the environment as may be forced upon it but that many of the things done are in spite of that environment. "Belief and ceremonial are adapted to, and sometimes turned into new channels of development by economic and political stimuli; and it is also clear, as will be seen, that religious concepts may deeply affect economic and social development and may limit or even prevent adaptations that are obviously possible. Nevertheless, the power of ceremonial, magical practices and fundamental religious attitudes to transgress economic and political boundaries on a large scale is, I believe, undeniable . . . "

The text is organized in four parts: (I) Food Gatherers, (II) Cultivators, (III) Pastoral Nomads, and (IV) Habitat and Economy.

Warning the reader that peoples are rarely absolutely of one economic pattern, the author selects for his first group the Malay forest-dwelling Semang and Sakai; the Kalahari Desert Bushmen; the United States Great Basin Paiute and the Blackfoot of the bison plains; fishing peoples of British Columbia; the reindeer-hunting Yukaghir of Siberia; and the Eskimo. No one of these seems to recognize the cultivation of plants as a means of supplying food. On the other hand, more or less vegetable food is used but taken as found. Nor are domestic food animals a part of the plan. The author points out that, although these peoples are in daily contact with the flora and specialize in hunting, they do not experiment with either agriculture or domestication.

The second group of peoples are the cultivators, such as the Boro of the Amazon; the Yoruba and Boloki hoe cultivators of the African forests; the Solomon and Society Islanders; in the United States, the Hopi and Yuma, flood-land farmers in an arid country; and the people of Cochin in India. All of these are actively engaged in some simple form of agriculture, the last being the only one to use a plow. Fishing, hunting, and gathering may still play an important varying role in these tribal economies, so that the distinguishing characteristics may not lie in the total presence or absence of agriculture but in the type and magnitude of agricultural production.

Dense, inland populations seem wholly dependent, directly or indirectly, on intensive agriculture. It may be remarked in passing that wheat is missing from the list of cultivated plants for this group, though rice, maize, and millet flourish. All that this means is that wheat and its immediate allies and the wide use of animal power are fundamental matters in the cultures underlying modern Europe.

Part III presents the Masai of East Africa as cattle herders; the Ruwala Badawin of Arabia as camel breeders; the Kazak, Kirghiz, and Kalmuck of Asia as herders of sheep and horses; and the reindeer herders of Siberia. The environments range from tundra to arid plains but are for the most part unforested areas. Furthermore, the herd or flock must be provided with seasonal or at least alternate pastures, so that the community must follow. Nevertheless, some agriculture may be maintained, as among hunting peoples. The author seeks to remind the reader that each type of economy has its history, as in Africa where tribes with highly specialized cattle patterns subjected millet-raising tribes, so that in the end a society was constructed in which there were two classes, a cattle-raising aristocracy and an agricultural peasantry; again, elsewhere cattle raising is the work of men, agriculture of women.

As an introduction to the volume as a whole and in keeping with the geographical point of view, two interesting world maps are presented, one showing the main vegetation areas, the other the distribution of dominant economies of about the eighteenth century—plow cultivation, hand cultivation, pastoralism, reindeer breeding, food gathering. In the main, the peoples of the world at that time can be consistently included in such a scheme of classification, if placed according to the dominant types of food economies. There is some overlapping, but it is usually strictly marginal. One value of such a map is to bring home to the reader the regional segregations for such patterns. With these maps in mind, we turn to Part IV, Habitat and Economy. Under this heading is an up-to-date summary of historical, ethnographical, and archeological knowledge concerning the foregoing categories of primitive man's development that even the specialist will find of interest.

CLARK WISSLER

THE GREAT TREK AND OTHERS

Report to the Secretary of State for Dominion Affairs of the Inter-Departmental Committee on Migration Policy. 93 pp. (Cmd. 4689.) His Majesty's Stationery Office, London, 1934. 1s. 6d. 9½ x 6 inches.

ISOBEL EIRLYS EDWARDS. **The 1820 Settlers in South Africa: A Study in British Colonial Policy.** 207 pp.; maps, ills., bibliogr., index. (Royal Empire Society Imperial Studies, No. 9.) Longmans, Green and Co., London, New York, etc., 1934. 7s. 6d. 9 x 6 inches.

ERIC ANDERSON WALKER. **The Great Trek.** xii and 389 pp.; maps, index. (The Pioneer Histories.) A. & C. Black Ltd., London; The Macmillan Company, New York, 1934. $5.00. 9 x 6 inches.

JAMES G. LEYBURN. **Frontier Folkways.** x and 291 pp.; bibliogr., index. Yale University Press, New Haven, 1935. $3.00. 9½ x 6½ inches.

Independent individual migration and settlement by infiltration versus government-controlled group settlement—thus tersely might be stated the main question before the Inter-Departmental Committee on Migration Policy. The Committee's findings are discouraging to those who see in group settlement a "heroic remedy" for population maladjustment. "Schemes for settling many thousands of families overseas in new communities, involving as they may do the chartering of ships, the building of ports and railways, the construction of roads, the selection of a balanced population containing the right number of agriculturalists, tradesmen, professional men and others, the co-operative buying and selling of all that the new communities

will need or produce, and the writing of new names on the map tend to impress the public by the magnitude of the organisation involved, of the sums to be expended and of the results, in new towns overseas, which they promise. There is nothing spectacular, on the other hand, in the idea of an individual father of a family walking into a passenger agent's office, producing a voucher for a nominated passage for himself and his family, and sailing overseas to try his luck in an opening secured for him by a friend or relative who has previously done the same. It seems to us, however, that the relative merits of these two lines of approach must be judged by results. We find it very difficult to believe that organised group settlement could deal with, at the most, more than 2,500 families—say, 10,000 souls—in a year; neither the localities, nor the capital, nor the administrative capacity for anything in excess of this—or perhaps for anything as large as this—are available."

The Committee's sober and considered attitude towards migration may be illustrated by further quotation. "The question of migration cannot be considered in isolation from the general economic conditions with which it is inextricably interwoven. There is no foundation for any idea that because there may be, at the moment, a surplus population in this country [United Kingdom], and vast areas of unoccupied land in some of the Dominions, a simple act of transference of the former to the latter will of itself solve the problems involved." "The history of migration in modern times proves that migration is a symptom of prosperity and not a cure for depression. The real stimulus to the individual to migrate is the hope of securing a better standard of living overseas. The right line of approach to a more desirable redistribution of the white population of the Empire, therefore, is not to endeavour to transfer men and women from the United Kingdom overseas regardless of economic conditions such as the possibility of marketing their produce, and to maintain them there until (if ever) they are in a position to maintain themselves, but to do all that lies in our power to assist in creating the conditions overseas which have in the past provoked and will in the future provoke a large volume of spontaneous migration."

In the decade 1922–1931, when new settlement schemes were being tried out, two-thirds of the migrants from the United Kingdom to the British Empire overseas made their way without government aid, while only 3 per cent proceeded to group settlements. Even so this represents a departure from traditional policy. Only in a small number of cases and on a comparatively small scale had the group-settlement scheme been tried out before. One case was the 1820 settlement in South Africa. And this, the Albany Settlement, affords an excellent illustration of the disasters following lack of economic planning.

The motive of the Albany Settlement was basically political, in large part the creation of a defensive frontier against the Kaffirs across the Great Fish River. The policy in its various ramifications is the thesis of Dr. Edwards' book. On the economic side the settlement was an attempt to plant an agricultural community in a region whose characteristics were all too well described by its Dutch name, Zuurfeld. Sour soils, failure of the rains, and rust in the wheat in three years brought the hapless little colony of migrants fresh from Britain to the verge of collapse. A majority left; the remainder were saved only by the reversal of official policy permitting grants large enough for pastoral farming.

Apropos of group settlement the Inter-Departmental Committee observes that "people born in the Dominion concerned are as a rule better equipped to cope with the difficulties of pioneering in new country than migrants from the United Kingdom." A South African illustration in point is to be found in the contrasts between the Albany Settlement and the settlements of the Voortrekkers. The story of the Great Trek (1835–1848)—"what manner of folk the Trekkers really were, why they trekked, and what they did on trek"—is told in a living and moving narrative by Professor Walker. A short chapter, "By Way of Introduction," gives an excellent setting. The numbers involved in the Great Trek, the distances traversed, and the

obstacles overcome are compared with those of the westward movement in the United States. The resulting problems, native and political, are touched on. The Trek made a nation, and while the Boer republics, the offspring of the Trek, lost the South African War, they "won the peace." "The Union to-day is dominated politically by the Trekker North."

On what manner of folk the Trekkers were some data may be found in "Frontier Folkways," a sociological study of frontier days in various regions including the Massachusetts Bay Colony (1629–1650), the Saint Lawrence (1660–1698), New Zealand (1839–1857), Bahia (1549–1580), Australia (1787–1840), and the Transvaal (1835–1899).

Mediterranean France

Jules Sion. **La France méditerranéenne.** 222 pp.; maps, diagrs., bibliogr. (Collection Armand Colin, No. 164.) Librairie Armand Colin, Paris, 1934. 10 fr. 50. 6¾ x 4½ inches.

Professor of geography at the ancient university of Montpellier on the Mediterranean border of France, Jules Sion is at home in his subject in more senses than one. He has long lived under the transparent blue skies and felt the cold blasts of the mistral that he so eloquently describes in "La France méditerranéenne."

In turn the climate, the vegetation, and the topography of Mediterranean France are discussed. A chapter on coastal forms, including the offshore bars and lagoons so beautifully developed west of the Rhone delta, and another on the adjacent sea and its life complete the picture of the natural environment to which the first part of the volume is devoted.

The work of man is discussed in the second and larger part of the book. Here are chapters on political geography, commerce on both land and sea, agriculture, industries and fisheries. The distribution of population and its migrations and the character of the prevailing rural habitat are then described. An authority on peasant life as affected by its geographic setting, Sion quickly unrolls to our view a picture of rural life in Mediterranean France very different from that in other parts of his country. Here the requirements of security on the part of a population exposed throughout long centuries to the passage of hostile hordes have increased the tendency toward grouping in protected sites and reduced the proportion of scattered population to abnormally low figures. An account of the principal cities—Montpellier, Nimes, Marseille, Toulon, Nice—and a concluding chapter on adaptations of the people to local environment, their relations with the other provinces of France, and kindred topics bring to its close an excellent little treatise, which will take an honorable place among the contributions to regional geography that constitute one of the most characteristic products of the French school.

Douglas Johnson

The Mediterranean Peninsulas of Europe

Max. Sorre, Jules Sion, and Y. Chataigneau. **Méditerranée, Péninsules méditerranéennes.** Part 1: **Généralités,** by Max. Sorre and Jules Sion; **Espagne-Portugal,** by Max. Sorre. Part 2: **Italie,** by Jules Sion; **Pays balkaniques,** by Y. Chataigneau and Jules Sion. Part 1, 234 pp.; Part 2, pp. 235–597; maps, diagrs., ills., bibliogrs., index. (Géographie Universelle, Vol. 7.) Librairie Armand Colin, Paris, 1934. Part 1, 70 fr.; Part 2, 100 fr. 11½ x 7½ inches.

A beautiful book. The photographs are a delight for clarity and illustrativeness. The reviewer finds Part I somewhat long on geology and history, though the mass of information the authors possess about the region is delightful. How could they help putting in a vast amount of historical detail in a region where so much of human civilization was wrought out? Nevertheless it is bewildering when we seek a picture

of the region as it is. A criterion would be: does the historical detail offered help us understand the life of today? Is the daily life and work of people in Granada different from that in Asturias because of the long Moorish domination in the south? One would suppose the local language would reflect these things? On such matters the book gives us nothing. But it may be that the authors desired to account for a good deal of the geography of earlier days.

It is interesting to learn that the true Mediterranean zone lies between sea level and 150 to 200 meters and that this zone is more shaken by earthquakes than any other region in the world. Of the Mediterranean as a sea rather little is said. Motive power of all currents is found in Gibraltar's east-flowing 59 million cubic meters "d'eaux diluées," but no mention is made of the fact that the surface of the Mediterranean lies 50 to 70 centimeters lower than that of the Atlantic, though the evaporation that causes this is brought out.

The Mediterranean lands still send out mostly products of their soil or subsoil and import mainly manufactured goods in ships—more than half of them foreign. Most of the traffic from Suez goes direct to Gibraltar, the Mediterranean lands lying to one side. Life is rural and individualistic; patriotism very local, to city rather than to state.

England dominates the sea. The part France has played is stated clearly but without undue emphasis. It would be most gratifying if French geographers would attempt to tell us how much of France is really Mediterranean, but nothing like that is given here. An attractive rubric—"The Place of the Mediterranean in Humanity"—is not convincingly elaborated.

Transhumance has always prevailed but is now declining because there are more boundaries of new nations to cross. Agriculture has been extensive, giving the ground little and getting little from it, but now a fifth to a half of the exports are dried fruits, produced by extremely intensive agriculture with the help of irrigation. The food crops, wine and olives, have spread along the coasts with civilization; the orange and lemon, money crops, are grown wherever steamers will call for them. There are more grapevines than olive trees. Most of the grapes are cultivated on the plains, but the best wines come from hill slopes. Wine making by and large is not intelligent.

As the climate is not too severe, it is possible to get along with moderate clothing and housing, and the Mediterranean folks eat much less than the French and English —not half of what the Americans eat. Going without is a custom of the region. The Italians have 3.4 per cent of their food animal, the French 7.9 per cent, and the English 19.3 per cent. The peasant in Italy eats meat but once a week. The farmer expects to raise his own food and grows several different crops at the same time. Fishing is not well developed. Italy imported 44 million lire of fish in 1929. The whole region lacks fuel, and even water power is but moderate. Tradition in the Mediterranean has had a strong influence. The miserable Rome of the fourteenth century would probably have perished but for the memory of ancient Rome.

The greater portion of Part I deals in detail with Spain and Portugal. There are many, though not quite enough, excellent little diagrammatic maps of regions. Especially missed is a rainfall map of the whole peninsula. The aridity map at page 81 has interest, but it is not enough; besides it conveys an erroneous impression with the same shade of lining for very arid and very moist. Much about the book appears to assume that the reader knows about things already or at any rate is eager to puzzle things out. Oftentimes he will simply misunderstand. All the diagrams are clever and beautifully constructed, but a number are marred by failure to make intensity of shade correspond to intensity of phenomena. The colored relief map of Spain and Portugal is disappointing: pretty but too small. Portugal's separateness is ascribed to the Atlantic, "which makes the horizon of every hilltop view."

Railways are rather thinly treated. There is a little map (p. 200), and we are

told of Spain's intentional choice of a wide gauge. The "piercing of Somport" is mentioned quite casually but not described, nor is there any account of the present condition of Barcelona's proposed European-gauge line to Paris. Fixed auto routes for passengers and freight now cover three times the mileage of the railways. The authors are sure that this will break up Spanish provincialism. So is the reviewer, but he believes education will do still more. Of this he finds almost nothing in the book. Education is enormously needed in Spain—technical schools, farm schools.

Spain lacks water and fuel too. Counting its maximum possibility in water power in terms of coal, it would amount with the coal to 13 million tons—less than half a ton per capita. For the United States the similar figure is 7 or 8 tons.

Supan pointed out in his "Bevölkerung der Erde" (1909) that Spanish cities include many country people in their population figures. Murcia, for instance, was not a city of 100,000 at all. Our author gives details for Murcia and Orihuela.

	MURCIA	ORIHUELA
City nucleus	32,318	11,117
Villages	45,125	5,081
Scattered houses	47,614	18,874
Total	125,057	35,072

We wish we had other similar data. How many are there in the city nuclei of Seville, Córdoba, and Madrid?

The work is rather difficult to read as a whole, since it was written so distinctly by parts. Perhaps the contrasts are too great for generalization and the strength of the authors lies in detail.

It is an admirable book. We have to own a copy.

MARK JEFFERSON

The second part is likewise devoted in the main to detailed accounts of many small regions. This method is especially appropriate to Italy and the Balkans, where local differences in land forms, climate, and vegetation are marked and where the people of almost every lowland and mountain range exhibit pronounced individuality. Clean-cut maps bring out sharp regional contrasts in densities of population: small pockets teeming with people are set in the midst of wildernesses—barren karstic plateaus, forested uplands, malarial plains—but even more striking are the contrasts in terms of progress. To the geographer part of the charm of Mediterranean Europe lies in the close juxtaposition of the modern, the medieval, and the primitive.

Since "people constitute the principal raw material of Italy," stupendous efforts are being made by the Fascist regime to do away with primitive conditions that reduce the effectiveness of the human resource. Italy not long ago was notorious for its fevers and high death rate but today is not unhealthful except for a few swamps and marshes. Malaria caused 21,000 deaths a year about 1885; now it causes only 2000 or 3000. A great program of *bonifica integrale* is being carried out, involving the regulation of torrents, the draining of marshes, the control of landslides, etc. The program is "integral" in that it takes into account all land not being put to the best use. Its guiding purpose is to hold the peasant to the soil. With the passing of the old and often wasteful practice of transhumance, population is flowing downhill from the uplands.

What accounts for the short-lived glory of the Athens of the fifth century before

Christ? For the power and fall of ancient Rome? Professor Sion touches upon these eternal questions of the Mediterranean world. The central position of Athens in the Aegean "rendered possible a thalassocracy that extended from the Hellespont to Sicily. But the splendor of Athens is no more to be explained by natural causes than the Parthenon by the purity of the Pentelic marble." Rome's early strength may be ascribed partly to the incomparable military advantages of her site, but "it was necessary that [she] become strong through the spirit of her institutions before she could put to profit [the geographical] features that facilitated her conquests." With the expansion of her commerce under the late Republic and Empire, agriculture was allowed to decline in the regions around the metropolis. "Imperial Rome lived . . . on the whole ancient world," and "when she was no longer mistress of the universe nothing was left for her" to draw upon. "This in part explains the profundity of her fall." The Rome and the Athens of today are creations of tradition and sentiment. Geographical factors have played but a small role in their rapid recent growth.

On a linguistic map of the Balkan Peninsula no less than twenty different symbols indicate tongues and dialects and disclose something of the human disunity of the region. In a short paragraph Professor Chataigneau suggests the wide variety of psychic types associated with differences in speech and faith: the "patient and meticulous" Slovene mountaineer; the gay, artistic Croat; the Bulgar, hard-working and conscientious but not without a sense of humor; the Serb of the Šumadija, "a skillful promoter of collective aspirations." Someday means will perhaps be devised for the precise measurement of these intangibles, and future editions of the "Géographie Universelle" may well include maps showing the distribution of some at least of the elements of group psychology that have so often influenced the trend of history.

An American-Mexican Frontier

Paul Schuster Taylor. **An American-Mexican Frontier: Nueces County, Texas.** xiii and 337 pp.; map, ills., index. University of North Carolina Press, Chapel Hill, 1934. $3.50. 9¾ x 6¼ inches.

The end papers of Dr. Taylor's book show the distribution of Mexican children of school age in Nueces County, Texas; they constituted half the total population of school age at the scholastic census of 1929. Nueces County is a great cotton producer—it led in cotton production among counties of the United States in 1930—and the pickers are mainly Mexican. Dr. Taylor's study is an analysis of the socio-economic relations between Mexicans and whites focused upon the county but departing from its limits, especially in the discussion of the historical background. In Nueces County the "past lives vividly in the present." It is the old story of conflict along a frontier. "The Indians, enslavers in 1529 of the first exploring whites, have been completely ousted from the area for two generations. Mexicans, entering as colonizers in the eighteenth and nineteenth centuries, were driven from political control by the wars of Texan Independence and of Mexico against the United States, and lost their position as landowners; but other Mexicans have assumed economic rôles of importance, first as vaqueros and shepherds, now as cotton laborers. The whites have wrested both economic and political control from Mexicans, but the structure of their society is based more firmly than ever on the labor of a large Mexican population. Negroes have been present from the days of the explorers, always a minor element, always subordinate."

Thus Dr. Taylor's volume fills a double role—as an addition to his study of the problem of Mexican labor in the United States (compare *Geogr. Rev.*, Vol. 23, 1933, p. 505) and as a contribution to the human geography of frontiers.

The Economic Development of Inner Mongolia

Yin-T'ang Chang. **The Economic Development and Prospects of Inner Mongolia.** xiv and 243 pp.; maps, ills., bibliogr., index. The Commercial Press, Shanghai, 1933. $2.50 Mex. 9 x 6 inches.

With the loss of her northeastern provinces, China is giving increased attention to the northwest. This informative volume on Chahar, Suiyüan, Ningsia, and neighboring areas reflects a phase of this interest. In five chapters there is a general consideration of the physical characteristics of the chief natural regions, their historical background and economic activities, and the possibilities of Chinese colonization.

The author is now a member of the Department of Geography at Tsinghua University in Peiping, but much of the work was done under Professor Roxby at Liverpool. The study has the merit of familiarity with Chinese source material, including historical writings with their many changes of place names. It is essentially a compilation from scattered literature, without mention of field experience on the part of the author. Numerous questionable generalizations from random sources illustrate the grave dangers of drawing on miscellaneous writings without having a sense of proportion gained through personal travel. Unfortunately, as there are a number of statistical misprints, one should not use the material without access to the printed list of errata (45 items; 12 additional corrections have been supplied by the author).

Perhaps the most interesting chapter is that dealing with the northwest as a field for Chinese colonization. In many cases the grazing grounds of the Mongol banners have been taken over by coercion or through sale by dissolute princes in Peiping. Chang estimates the probable future expansion, through further reclamation of arable land, the improvement of land already cultivated, the development of grazing, and in Manchuria through industry as well, at a grand total of 154,910,000 people, distributed as follows: Chahar, 10,000,000; Suiyüan, 15,000,000; Ningsia, 1,000,000; Outer Mongolia, 1,000,000; Chinghai, 2,000,000; Sinkiang, 40,910,000; and Manchuria, 85,000,000.

In the opinion of the reviewer these estimates are too optimistic to be sound. The Mongolian borderlands and Sinkiang are regions of precarious agriculture. Cultivation has already spread over the steppe to dangerous limits, so that in many areas, including districts within the Great Wall, the problem is not colonization but decolonization. Irrigation from wells or rivers is not generally available, and with the highly erratic rainfall of desert margins frequent crop failures must be expected.

In this connection it is appropriate to call attention to the present status of the large Saratsi irrigation project which draws water from the Hwang Ho to the west of Kweihwa. More than $800,000 (Mex.) has been spent by the China International Famine Relief Commission, most of it American capital, and the engineering work is practically finished. It is now apparent, however, that the soil is dangerously alkaline, and the raising of the water table by the canal system is further increasing the surface concentration of salts. While no final decision has been reached, it appears possible that most of the project may be abandoned. This was regarded as the most hopeful undertaking in all of Inner Mongolia. George B. Cressey

Distribution of Fresh-Water Mollusks in the U.S.S.R.

W. I. Shadin. **Uber die ökologische und geographische Verbreitung der Süsswassermollusken in der UdSSR.** Maps, bibliogr. *Zoogeographica*, Vol. 2, 1933–1935. pp. 495–554.

This paper is a first attempt at a general treatment of the ecological and geographical distribution of the fresh-water mollusks of the entire U. S. S. R. The chief ecological factors considered are motion (or lack of motion) of the water and its temperature, depth, and chemical constitution.

The present geographical distribution was chiefly determined by the local or regional extermination of the mollusks by the Quaternary glaciations and accompanying marine transgressions, by climatic changes in the unglaciated regions, by increased swiftness and muddiness of the streams, and by the ability of the mollusks to spread. Mollusks of standing waters disperse from one body of water to another in various ways—especially by help of birds and insects. Mollusks of running waters spread from one river system to another almost exclusively through man-made canals. As a consequence and because of local insurmountable obstacles to the spread, the mollusk fauna of lakes and ponds is fairly uniform, whereas that of streams has a different composition in different regions and in several regions is very poor. The rivers of eastern and central Siberia are inaccessible to the Amur-Chinese mollusks because of mountain barriers and to the European stream mollusks because of the ecological barrier of Ob River. Therefore the Yenisei basin is populated only by mollusks that came from Lake Baikal; and the Lena and other rivers to its east are still lacking stream mollusks. Kamchatka and Crimea are other faunistic islands. Because of topographic barriers the mollusk fauna diminishes in species eastward in the European part of the U. S. S. R. Some mollusks, as *Hydrobia steini* and *Dreissensia polymorpha*, appear to be glacial relicts. Temperature is a decisive factor for the distribution of some, but distinctly not for most, mollusks.

ERNST ANTEVS

LATE-QUATERNARY CLIMATE CHANGES IN NORTHERN EUROPE

ROLF NORDHAGEN. **De senkvartære klimavekslinger i Nordeuropa og deres betydning for kulturforskningen (Late-Quaternary Climatic Changes of North Europe and Their Relation to Archeology).** x and 246 pp.; maps, diagrs., ills., bibliogr. (Publikasjoner Inst. for Sammenlignende Kulturforskning, Ser. A, No. 12.) H. Aschehoug & Co. (W. Nygaard), Oslo, 1933. N. Kr. 3. 7¼ x 5½ inches.

The first half of this book discusses the habitableness of Norway during the last interglacial and glacial epochs. From the fact that in Denmark the last interglacial was essentially warmer than the modern age it is concluded that the Scandinavian peninsula also had a more southerly flora and fauna during the last interglacial than at present.

The absence of glacial drift and of ice scouring in some coastal regions and the occurrence of sharp-pointed mountain peaks that are the result of ages of frost weathering show that the last North European ice sheet was not extensive and thick enough to cover all Norway. The mountain flora supplies additional evidence; for it includes North American-Greenlandic species that could not have reached Scandinavia during the postglacial epoch. The American plants and others that are found outside the Scandinavian mountains only in the Alps, Siberia, and other remote regions occur largely in two districts, viz. in the Dovre and Trollheimen region (about 62½° N., 9° E.) and in the mountains between the Saltfjorden (67¼° N.) and the Porsangerfjorden (70° N., 25° E.). The plants may have survived the last glacial epoch in the coast regions southwest of Trondheim (between 62¼° N. and 63½° N.) and in the skerry guard and on the peninsulas between the Saltfjorden and North Cape. There seem to have been other areas of survival around the mouths of the Boknfjorden and Sognefjorden in western Norway and on the north coast of the Varangerhalvöya east of North Cape. Evidently animals survived in the ice-free areas. The plants have migrated to their modern regions in the mountains during postglacial times.

Nordhagen advances the hypothesis that perhaps man also survived the last glacial epoch in coastal regions of Norway and that records of this are to be found in the Komsa culture of Finnmark Fylke, northernmost Norway, and perhaps in other

cultures found southwest of Trondheim. The Komsa culture is regarded as late Mousterian-Aurignacian, and the Aurignacian is referred to the last interglacial; but, because of its isolation by the ice sheet, the Mousterian-Aurignacian culture on the Norwegian coast is believed by Nordhagen to have retained its characteristic features until the end of the glaciation. If the Komsa culture is not of interglacial and glacial age, it is, according to Nordhagen, at any rate of Subarctic age. The prevailing opinion is that the Komsa people immigrated on the transition between the Subarctic and the Boreal epochs (see Halvor Rosendahl, *Norsk Geol. Tidsskrift*, Vol. 13, 1933, pp. 313–317). Norway thus seems to have been inhabited by man for 9000 to 10,000 years.

The latter half of the book treats of the late-glacial and postglacial climates of Scandinavia, the peopling of the peninsula, and the human cultures. The climates are primarily judged by the rate of the ice waning, the immigration and spreading of the biota, and the evolution and succession of the plant and animal communities, as deciphered from lake sediments, peat bogs, calcareous tufas, shell beds, etc. As data accumulate, the climatic evolution proves to be more complicated than earlier held, but the old stages Subarctic, Boreal, Atlantic, Subboreal, and Subatlantic are retained. For instance, the Subboreal period, which was on the whole dry, is now known to have had rather marked fluctuations in precipitation; and, although the marine mollusks indicate that the sea temperature was distinctly higher than today, the deciduous trees were in retreat and the pine was spreading over wider areas.

The temperature seems to have risen above that of today during the Boreal epoch about 8500 years ago and to have sunk to the modern level during the Subboreal age some 3500 years ago. About 600 or 500 B.C. according to Swedish records, or 850 B.C. according to Central European records, the temperature dropped distinctly below its modern level and the precipitation increased quickly and very considerably—the Subatlantic epoch. Since about 800 A.D. the mean temperature seems to have been about as today, and the precipitation has undergone but small fluctuations. The unfavorable turn of the climate during the first part of the Subatlantic epoch caused a great southward retreat of settlement.

ERNST ANTEVS

THE ESKER PROBLEM

V. TANNER. **The Problems of the Eskers: IV. The Glacio-Fluvial Formations of the Rasse'muetke Valleys, Petsamo, Lapland.** 118 pp.; maps, diagr., ills. *Fennia*, Vol. 58, No. 1, 1934.

This is the fourth of a series of papers by Väinö Tanner devoted to the investigation of peculiar and yet representative Finnish eskers (compare *Geogr. Rev.*, Vol. 22, 1932, pp. 521–522). The field selected for study is the Rasse'muetke Valley in northern Lapland. Glaciofluvial material covers the valley bottom from side to side and forms a landscape of complex plateaus, ridges, terraces, hillocks, and pits. To facilitate the analysis of these deposits in a region where form alone can be studied since sections are almost completely lacking, Tanner has constructed a combination contour and hachure map of a 3½-mile (5½-kilometer) section of the valley on a 1 : 6000 scale. All places mentioned in the text are referred to the map by a system of squares that are indicated by letters and figures. This method reduces the readableness of the report but appears indispensable to a student following the minute and essential details of the place descriptions and the fine photographs that accompany the text.

According to Tanner, the movement of the continental ice over this district was from southwest to northeast until the waning stages of glaciation, when the highlands were exposed and inactive ice tongues shaped themselves to the valleys. The bare hilltops and valley sides indicate extensive washing away of the ground moraine by marginal streams of torrential proportions, especially when these streams were

supplied by the waters of suddenly drained glacial lakes. This drift cover from the higher ground was swept to lower levels, where it was deposited along the sides of the ice tongues to form kame terraces or was spread over the ice to fill crevasses and spaces behind and beyond the ice front. Thus for any great discharge of sediment-laden water a continuous flood plain was built within the area of rotten ice, terminating in a delta at the late-Glacial sea level, which is now a marine limit about 266 feet (81 meters) in elevation in this region. Melting of the ice has left the marginal flood plains in the form of partially collapsed terraces and isolated plateaus which have a gently graded profile of the extant original surfaces. Connecting the plateaus but seldom rising to their level are narrow eskers with steep slopes at or near the angle of repose for gravel. These appear to have been narrow portions of the flood plain that formed within cracks in the ice and then collapsed to a slope of equilibrium after the supporting ice walls melted. Several parallel graded profiles are recognized by Tanner among the disconnected plateaus and are interpreted as remnants of successive flood plains formed by successive discharges of water over the subsiding surface of the disintegrating ice in Rasse'muetke Valley.

On the basis of the plateau profiles, the extreme coarseness of some of the esker materials at critical points, and the fact that many sharp esker ridges are successively followed by level-crested esker ridges that in turn gradually merge into real plateaus Tanner makes a strong case for a superglacial river origin for eskers in northern Finland. Although he emphasizes reasons for the failure of other theories of esker origin when applied to Rasse'muetke Valley, he wisely concedes that eskers may be formed in different manners and thus takes no exception to the hydrostatic theory of subglacial river origin for which De Geer has presented compelling evidence in southern Fennoscandia.

RICHARD J. LOUGEE

DETERMINATIONS OF GRAVITY AT SEA

F. A. VENING MEINESZ, with the coöperation of J. H. F. Umbgrove and P. H. Kuenen. **Gravity Expeditions at Sea 1923–1932. Vol. II: Report of the Gravity Expedition in the Atlantic of 1932 and the Interpretation of the Results.** 2 and 208 pp.; maps, diagrs. *Publ. Netherlands Geodetic Commission*, Delft, 1934. 12 x 9½ inches.

This volume is largely devoted to a study of the gravity results contained in Volume I (reviewed in *Geogr. Rev.*, Vol. 23, 1933, pp. 699–700), but in addition it presents the results of the Expedition of 1932 in the eastern part of the North Atlantic. The first chapter of nearly sixty pages is taken up with a theoretical discussion of the interpretation of gravity results. The fact is emphasized that, although the figure of the earth may be calculated from geodetic and astronomical measurements, such calculations must be confined to data obtained over the land portions of the earth. A more reliable figure, however, may be determined from gravity results, because now, with accurate gravity measurements possible at sea, data for the whole earth may eventually be included in the investigation. The use of gravity measurements in geophysical studies of the earth's crust is also discussed.

In the third chapter is given what is probably of greatest interest to geodesists, a table of anomalies based on the five different methods of reduction, namely the free air, the Bouguer, and three isostatic methods—the Hayford-Bowie, the Heiskanen, and a special "regional" method devised by Dr. Meinesz. Only a cursory glance at the anomalies is needed to show that any one of the isostatic methods is vastly superior to either of the other two in making the anomalies small—that is in making the theoretical value of gravity conform with the actual observed value at any point. As an aid in studying the relative merits of the three isostatic methods and in trying to detect relationships with the undersea topography, a very interesting

series of profiles of the ocean bottom is included for numerous groups of stations, and on these have been superimposed curves showing the three kinds of isostatic anomalies.

The remainder of the book deals chiefly with the geophysical interpretation of the gravity results and anomalies. Two chapters are given over to an interesting discussion by Dr. Umbgrove of the geology of the East Indies, one on the relation between the geology and the gravity field and the other on various theories regarding the origin of the East Indies. In another chapter Dr. Kuenen discusses the relation between submarine topography and gravity. The remainder of this section is by Dr. Meinesz himself and sets forth his own theories about the interpretation of gravity results. Although many geodesists do not agree with certain of Dr. Meinesz' theories, all will give him credit for much deep study on the subject and for inspiring leadership in this field of geophysical investigation. His interpretation of the great negative gravity strip in the East Indies warrants careful consideration. This tremendous anomaly of the gravity field may tell us much about the crust of the earth if a complete explanation can be found for it.

The tables giving the data of the isostatic reduction are not bound with the publication but are furnished in loose form in an accompanying envelope. No other fault, if this is one, can be found with this beautifully printed book. Except for his most recent expeditions, Dr. Meinesz has presented in this and in Volume I the complete results of a great pioneering undertaking to which he has given many arduous years and tremendous enthusiasm. Our geophysical knowledge of the crust of the earth has been materially advanced by his devotion and efforts, in which he has been actively and ably assisted by the Netherlands Navy and by the Netherlands Geodetic Commission.

C. H. Swick

Pollen Analysis

H. Godwin. **Pollen Analysis: An Outline of the Problems and Potentialities of the Method. Part I, Technique and Interpretation; Part II, General Applications of Pollen Analysis.** Maps, diagrs., bibliogrs. *The New Phytologist*, Vol. 33, 1934, pp. 278–305 and 325–358.

This paper has been written, as the author explains, to supply the need for a simple general statement of the scope and limitations of pollen analysis. Critical rather than exhaustive, it aims to present a general picture of what the method can and cannot do, having an eye particularly to applications within the British Isles. In many respects it is one of the most helpful documents that have appeared in its field in English.

Technique and interpretation are first discussed, with particular attention to sources of error. Like most others who have considered this phase of the subject, the author agrees that pollen analysis justifies itself pragmatically. Despite very obvious difficulties and imperfections, it seems to work remarkably well. Perhaps he would object to the construction, but it is not far off to say that pollen analysis, like medical diagnosis, when all is said and done, is less method than art, based of course on science and serving scientific ends. To a great extent those standards and controls which are so comforting to the experimental scientist are still devoutly to be sought.

The second part of the paper deals with pollen analysis as a key to regional history and a means toward the establishment of arbitrary time scales. The interpretation of local vegetation histories is analyzed from the viewpoint of the ecologist—a service that should go far toward enabling other workers to discriminate between edaphic and climatic influences in the pollen profiles they develop.

Diagrams illustrating regional parallelism in various parts of Europe show contemporaneous changes in vegetation through the course of the postglacial record and

are at once striking and convincing. There follow an illuminating discussion of the correlation of forest history with other time indices—geological, climatic, and archeological—and a final brief discussion of applications in the British Isles. Many species that on the continent are important indicators of climate did not have access to Great Britain during the postglacial migrations. The absence of their pollen from the British profiles indicates the necessity for an independent system of correlation that, once firmly established, can be tied back into the sequence on the mainland of Europe.

PAUL B. SEARS

A SPITSBERGEN COALFIELD

ANDERS K. ORVIN. **Geology of the Kings Bay Region, Spitsbergen, With Special Reference to the Coal Deposits.** 195 pp.; maps, diagrs., ills., bibliogr. *Skrifter om Svalbard og Ishavet No. 57*, Oslo, 1934. Kr. 20. 10¼ x 7 inches.

Although coal is present in earlier formations in Spitsbergen, only the Tertiary and late-Mesozoic seams are of any commercial value. The Kings Bay coalfield is of Tertiary age and is on the west coast in latitude 79° N. The occurrence of coal in this locality was noted as early as 1610 by the captain of an English whaler, but commercial mining operations were not begun till 1916. They were continued until 1929, when work ceased owing to the world slump in prices and the discouragement caused by a fatal explosion. The mines are now filled with ice, but the mining village is being maintained pending a possible resumption of work. The maximum output of 98,672 tons was made in 1927, when about 300 men were employed.

The Tertiary coalfields of Spitsbergen, and especially that of Kings Bay, are notable for the deformation of their strata by late-Tertiary folding. In fact, the field has been preserved among the surrounding older rocks only by reason of intense folding, thrusting, and faulting. The extremely complicated structures thus produced led to considerable difficulty in working the six exploitable seams. Drilling in the frozen ground raised interesting questions, theoretical and practical. The total quantity of coal in the field is estimated at 16.2 million tons, of which about 6.6 millions are regarded as workable.

Dr. Orvin's memoir is excellently arranged, written in good English, and beautifully illustrated. This is one of the finest memoirs that has yet been published by the vigorous and enterprising Spitsbergen department of Norway.

G. W. TYRRELL

A SELECTION OF GREEK GEOGRAPHICAL WRITINGS

E. H. WARMINGTON. **Greek Geography.** xlviii and 269 pp.; index. (The Library of Greek Thought.) J. M. Dent & Sons Ltd., London and Toronto; E. P. Dutton & Co. Inc., New York, 1934. $1.90. 7½ x 5¼ inches.

This volume well serves the purposes of the general reader who may wish to acquaint himself with the character of our sources for the early history of geography. That, I take it, is its main objective. On the whole the work is well done. The editor, who selected and translated the texts, was aware of the fact that he could not present all the relevant evidence, and in a work of this character he could not of course present novel views. The reader, consequently, will not expect light on disputed questions nor assume that the book provides him with the materials for a decision about them. Actually he will find an intelligent presentation of current views, especially in the Introduction and in the identification of places mentioned by the Greek writers. Mr. Warmington is well informed and has proved his ability to deal in a large way with matters requiring much knowledge of detail, notably in "The Commerce Between the Roman Empire and India" (1928).

W. A. HEIDEL

The Magic of Flying

ANNE MORROW LINDBERGH. **North to the Orient.** With Maps by Charles A. Lindbergh. 255 pp.; maps, ill. Harcourt, Brace & Co., New York, 1935. $2.50. 8 x 5½ inches.

"What essential quality has come out in the telling? It is not in the flying alone, nor in the places alone, nor alone in the time; but in a peculiar blending of all three, which resulted in a quality of magic—a quality that belongs to fairy tales. It was not that we arrived in Baker Lake on August third by plane, but that three hours of flying had brought us from the modern port of Churchill to a place where no white woman had ever been before. It was not only that we flew from Baker Lake to Aklavik in twelve hours, by the midnight sun, but that while flying over those gray wastes south of Victoria Land, isolated and wild as the moon, I could hear through my ear-phones the noisy chatter of big cities over the edge of the world. At northernmost Point Barrow, we flew into an isolated settlement, still waiting for its new year's supply of provisions, and flew out again, independent as the wind, passing their ice-blocked ship, far below us in the sea, on our way to Nome. Over the Chishima Islands in fog, radio told us of weather and harbors ahead. A barefoot fisherman took us into his thatched hut when we landed in bad weather in Kunashiri. The next morning, in clear skies, after a twenty-minute flight, we were in Nemuro and civilization. With nothing but flood beneath us in China, we were within easy distance of food and safety.

"It was a magic caused by the collision of modern methods and old ones; modern history and ancient; accessibility and isolation."

It was some such collision of worlds that enabled the "sea discoverers" of Elizabethan times so greatly to enrich the contemporary literature, and we may look to our "air discoverers" of today to make like contribution in their new travelers' tales. Not all travelers by air will be blessed with the poet's eye with which Mrs. Lindbergh saw a new world on the trip to China made with her husband in 1931. If she contributes "no geographical knowledge," as she says in her Preface, she gives heightened expression to geographical feeling whether describing the "austere and breath-taking moments" of flight over virgin territory or a new view of such familiar features as the Mackenzie-delta cutoffs, "silver sickles of water," or the dreadful realities of the Chinese rivers in flood.

Mrs. Lindbergh acted as radio operator on the flight, and one gains from her book a deep impression of the part radio communication plays in securing the "freedom of the air." "What time does it get dark at Nome?" In that urgent question, asked after the fliers had left Point Barrow and the "clear unbounded sea of day," is summed up one of the vital necessities in the conquest of this new world of the air.

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COLONEL BIGELOW, a lieutenant colonel on the retired list of the United States Army, is author of several books on military history and strategy. He has also long been interested in discovery and historical geography and has reviewed for magazines (among them the *American Historical Review*) works treating of these and kindred subjects.

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